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# Essays on Malawian agriculture: Micro-level welfare impacts of agricultural productivity; profitability of fertilizer use; and targeting of fertilizer subsidy programs

Francis Addeah Darko
*Purdue University*

# ESSAYS ON MALAWIAN AGRICULTURE: MICRO-LEVEL WELFARE IMPACTS OF AGRICULTURAL PRODUCTIVITY; PROFITABILITY OF FERTILIZER USE; AND TARGETING OF FERTILIZER SUBSIDY PROGRAMS

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Is approved by the final examining committee:

Jacob Ricker-Gilbert
Co-chair
Gerald Shively
Co-chair
John Sanders

Talip Kilic

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To God, my ever present help and strength, be all the glory

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# ABSTRACT

Darko, Francis Addeah. PhD. Purdue University, December 2016. Essays on Malawian Agriculture: Micro-level Welfare Impacts, Profitability of Fertilizer Use; and Targeting of Fertilizer Subsidy Programs. Major Professor: Jacob Ricker-Gilbert.

This dissertation comprises of three essays that address different aspects of agriculture in Malawi using a two-wave panel data collected by the National Statistical Office of Malawi with support from the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) program. Each essay stands alone as an independent study because of differences in research questions and the methodologies used in addressing the questions.

The first essay analyzes the micro-level welfare impacts of agricultural productivity. Welfare is measured by various dimensions of poverty and food insecurity; and agricultural productivity is measured by maize yield and value of crop output per hectare. Depending on the measure of welfare, the impact of agricultural productivity was estimated with a household fixed effects estimator, a two-part estimator or a correlated-random effects ordered probit estimator. The results indicate that increasing agricultural productivity has the expected statistically significant welfare improving effect, but the magnitude of the effect is small given the attention that agriculture usually receives. Efforts to effectively improve the welfare of rural agricultural households should therefore go beyond increasing agricultural productivity.

The second essay estimates the profitability of inorganic fertilizer use in maize production using fixed effects and multilevel models. The study finds that fertilizer use is generally unprofitable at prevailing market conditions when one assumes farmers incur positive transaction costs in the use of fertilizer. The main factor that drives low fertilizer profitability is low nitrogen use efficiency (NUE) which is estimated to range from 9.24kg to 12.09 kg on average, depending on the model specification. In order for fertilizer use to be profitable on average, the NUE would have to increase by at least 137% if maize output is valued at the farm gate price and by 50% if maize is valued at the lean season market price.

Essay three provides guidance for the targeting of Malawi’s Farm Input Subsidy Program (FISP) by estimating the difference in inorganic fertilizer use efficiency and crowing out of commercial fertilizer by subsidized fertilizer between poor and non-poor households. The difference in inorganic fertilizer use efficiency is estimated with a multilevel model of maize yield while the difference in crowding out is estimated with a double hurdle model of demand for commercial, inorganic fertilizer. The results indicate that non-poor farmers are significantly more efficient in the use of inorganic fertilizer, but have significantly higher levels of crowding out, compared to poor. This suggests that there is a trade-off between targeting the non-poor farmers and targeting poor farmers. Further analysis of the trade-off however indicates that targeting non-poor farmers instead of poor farmers, after accounting for the difference in crowding out, would result in an overall yield gain of 3.14 - 4.33kg per kilogram of nitrogen. Therefore the food security objective of Malawi’s farm input subsidy program would be better served if non-poor farmers are targeted instead of poor farmers.

# CHAPTER 1: INTRODUCTION

Agriculture continues to be the most important sector of Malawi's economy and an essential part of its social fabric, despite development in other sectors of the economy. The sector accounts for approximately 30 percent of gross domestic product (GDP), employs over 85 percent of households, and serves as the main foreign exchange earner (60 percent for tobacco alone in 2014). With about 74% of all rural income accounted for by crop production, agriculture is also the main source of livelihood for poor and rural households (Chirwa et al., 2008). The low share of agriculture in GDP relative to the large population and labor force employed in the sector proves that most people remain locked in low-productivity, subsistence agriculture.

By virtue of the fact that a majority of the poor and food insecure in Malawi live in rural areas and mainly depend either directly or indirectly on agriculture for livelihood, it is widely recognized that agriculture is a major channel through which poverty and food insecurity can be reduced (IFAD, 2010; Ehui and Pender, 2005). This notion is perhaps also based on the historical evidence that agriculture played an integral role in the marked success achieved in poverty reduction in Asia, and the evidence that growth in agriculture tends to be more beneficial to the poor than growth in other sectors of developing economies (DFID 2004). It is however not clear the extent to which improvement in agricultural productivity can impact the welfare of agricultural households.

Over the last two decades, agricultural productivity, as measured by maize yield, has been erratic. The factors that are commonly cited as underlying the agricultural productivity trend include weather variability (as Malawian agriculture is almost entirely rainfed), declining soil fertility, limited use of improved agricultural technologies and unsustainable land management practices, rationed agricultural extension services, market failures, and underdeveloped and poorly maintained infrastructure (World Bank, 2007).

In order to boost agricultural productivity and subsequently promote household and national food security, and also reduce poverty, the government of Malawi has been implementing a large-scale farm input subsidy program (FISP) since the 2005/2006 agricultural year. FISP currently provides inorganic fertilizers and improved maize and legume seeds to over 50% of rural, smallholder farmers at highly subsidized prices (about 95% subsidy). Each beneficiary is entitled to 50kg of Urea; 50kg of NPK 23:21:0; 5kg of improved maize seed or 10kg of open pollinated variety maize seed; and a kilogram of legume seed (Kilic et al., 2014). FISP is supposed to officially target Malawians who own a piece of land and are resident in the village/community, with special consideration to guardians looking after physically challenged persons, child-headed, female-headed and orphan-headed households (MoAFS, 2009; Chirwa et al. 2011). Empirical evidence suggest that the targeting of FISP has not been effective, and the effectiveness has likely undermined the impacts of the program (Kilic et al., 2014; Ricker-Gilbert et al., 2013; NSO, 2012).

With these considerations in mind, this dissertation identifies and addresses three different issues in Malawian agriculture: the micro-level impacts of agricultural productivity; profitability of fertilizer use; and the targeting of fertilizer subsidy programs. Each of these issues is organized into a standalone essay, i.e. each has its own set of research questions, empirical approached used in addressing the questions, results, and policy recommendations. All the essays are however based on the two-wave, nationally representative panel data from Malawi's Third Integrated Household Survey (IHS3), and Integrated Household Panel Survey (IHPS). IHS3 and IHPS were conducted by the National Statistical Office of Malawi (NSO) in the 2009/2010 and 2012/2013 agricultural years respectively, with support from the World Bank's Living Standard Measurement Survey – Integrated Surveys on Agriculture (LSMS-ISA) program. The data are described, albeit similarly, in each essay so that they stand alone. A summary of each of the essays is provided below.

## 1.1. Essay One: Micro-level Welfare Impacts of Agricultural Productivity

Essay one empirically estimates the impact of agricultural productivity (measured by maize yield and value of crop output per hectare) on various measures of household welfare in rural Malawi; and the effect of incremental changes of agricultural productivity on the poverty rate and the number of people that can be lifted out of poverty. Welfare is measured in terms of poverty and food insecurity. The poverty measures include per capita consumption expenditure, relative deprivation in terms of per capita consumption expenditure, poverty gap and severity of poverty; and the food insecurity measures include caloric intake and relative deprivation in terms of caloric intake. In addition to the poverty and food insecurity measures of welfare, the essay also generates another measure of welfare, called composite, welfare that combines the poverty and food security status of households. The composite measure of welfare is an ordered categorical variable defined as 1 for poor and food insecure households; 2 for non-poor but food insecure or poor but food secure households; and 3 for non-poor and food secure households.

The essay adds to the development economics literature by providing an SSA micro-level context to the existing literature on the welfare impacts of growth in agricultural productivity. To the best of my knowledge, Dzanku (2015) and Sarris et al. (2006) are the only studies that have addressed the micro-level welfare impacts of agricultural productivity in SSA. The essay improves upon and extends these studies in a number of ways. First, and perhaps most importantly, the essay considers additional measures of welfare such as relative deprivation index, poverty gap and severity of poverty that directly compare the welfare of households to that of other households or to a predetermined level of welfare. Second, the study extends the work of Dzanku (2015) and Sarris et al. (2006) by conducting a simulation analysis to estimate how incremental changes in agricultural productivity affect poverty and ultra-poverty rates as well as the number of people that can potentially be lifted out of poverty and ultra-poverty. Third, the essay controls for farm-wage income and income from off-farm economic activities that Dzanku (2015) and Sarris et al. (2006) could not control for. Dzanku (2015) also used panel data but the data is not nationally representative – it covered eight villages in two (Eastern and Upper East) of the ten regions of Ghana. Sarris et al. (2006) was based on a cross-sectional data from two (Kilimanjaro and Ruvuma) of the thirty region of Tanzania.

Depending on the measure of welfare, the impact of agricultural productivity is estimated with a household fixed effects estimator, a two-part estimator or a correlated-random effects ordered probit estimator. The results indicate that although increases in agricultural productivity have the expected positive impact on the welfare of rural agricultural households, the magnitude of the impact is small, given the given the attention that agriculture usually receives. The elasticities of per capita consumption expenditure and caloric intake to agricultural productivity range from 0.10% to 0.13% and 0.05% to 0.06% respectively, depending on the measure of agricultural productivity. The estimates indicate that a percentage increase in maize yield and value of crops per ha will decrease the probability of being poor and food insecure by 0.06% and 0.04% respectively; and increase the probability of being non-poor and food secure by 0.06% and 0.05% respectively. Simulation results further indicate that 50% increase in maize yield will reduce the poverty rate by 6.8 percentage points from 40.8% to 34.0%; and the ultra-poverty rate by just 2.5 percentage points from 11.0% to 8.5%.

Overall, the essay suggests that agricultural productivity would have to increase by a large amount in order to bring about the needed improvement in the welfare of rural, agricultural households. Thus, it is recommended that efforts to effectively improve the welfare of rural agricultural households should therefore go beyond increasing agricultural productivity.

## 1.2. Essay Two: Profitability of Inorganic Fertilizer Use

Essay two seeks to answer three research questions: 1) what is the level of nitrogen use efficiency (NUE) in maize production and how does it vary across the districts of

Malawi? 2) to what extent is the use of inorganic fertilizer in maize production profitable in Malawi? 3) how does the existing fertilizer subsidy affect the profitability of fertilizer use in maize production? The essay focuses on maize production because maize is the most widely cultivated crop in Malawi. It is cultivated by about 90% of farmers on 70% of their farm plots, and is the most important crop in terms of fertilizer application (NSO, 2013). The nitrogen use efficiency – the kilograms of maize obtained from the application of an additional kilogram of fertilizer – was estimated with fixed effects (district, enumeration area, household and garden) and multilevel models[1]. These model specifications together provide a good evaluation of the robustness of the estimates to model specifications. The profitability of fertilizer use is measured with Marginal Value Cost Ratio (MVCR).

The essay adds to the literature on fertilizer profitability in a number of ways. First, by virtue of the availability of a variable that identifies gardens over time in the two-wave nationally representative panels of data used in the analyses, this study is able to control for plot-level unobserved heterogeneity. Second, this study accounts for all maize prices – farm gate price, lean season market price and import parity price – that farmers can potentially face. While most farmers sell their produce at the farm gate, others sell at nearby market centers and depending on the month in which sales are made, face either the harvest season price or the lean season price. Apart from representing a price that farmers can potentially face in the maize market, the lean season maize price also represents the opportunity cost to farmers of purchasing maize if they are not able to

[1] A garden is defined as a continuous piece of land that is not split by river or a path wide enough to fit and ox-cart or vehicle, and can contain one or more plots.

produce enough maize to avoid household-level, seasonal maize deficits. The import parity price of maize is also considered in order to account for the government's opportunity cost to home production of having to import maize. Third, the present study extends the scope of previous work on fertilizer profitability by using the NUE and profitability estimates to provide guidance for the geographical allocation of fertilizer subsidies and to shed more light on the question of whether farmers would be better-off with subsidized fertilizer or the cash equivalent of subsidized fertilizer.

The results indicate that fertilizer use in maize production is unprofitable at prevailing market conditions when farmers are assumed to incur positive transaction costs in the use of fertilizer, an assumption that applies in Malawi. The main factor that drives low fertilizer profitability is low nitrogen use efficiency (NUE) which is estimated to range from 9.24kg to 12.09kg on average, depending on model specification. The essay also finds that in order for fertilizer use to be profitable in the production of maize, NUE will have to increase by at least 137% when maize is valued at the farm gate price and by at least 50% when maize is valued at the lean season market price. As expected, fertilizer subsidy improves the profitability of fertilizer by increasing the maize-nitrogen price ratio, but the study finds that, at all rates of subsidy, unless farmers can store their produce and sell during the lean season when maize prices are relatively high, farmers would be MKW 66.16 per kg of subsidized nitrogen better off with the cash equivalent of the subsidy than with subsidized fertilizer. Comparing the government recommended rate of fertilizer application to the rate at which farmers are currently applying fertilizer, it was found that the government recommended rate of application is between 116 - 119% more profitable.

Based on these finding, the essay makes five policy recommendations. First, NUE needs to improve in order to improve the profitability of fertilizer use. This can be done by encouraging farmers to apply organic manure and comply with the recommendation of applying basal fertilizer within a week after planting. Second, the Ministry of Agriculture and Food Security should encourage farmers to increase their current rate of fertilizer application to match the government recommended rate. Third, farmers should be encouraged to store their produce and sell during the lean season when prices are relatively high. The government can do this by promoting the use of improved grain technologies; and by providing farmers with credit during the harvest season so that they can defer the selling of their produce until the lean season. Fourth, efforts should be made to reduce the cost of fertilizer supply through investments in roads and infrastructure. This will increase the maize-nitrogen price ratio and consequently improve the profitability of fertilizer use. Fifth, unless farmers can be encouraged to sell their produce during the lean season instead of the harvest season, the government should consider transferring the cash equivalent to farmers in areas where NUE on maize production is extremely low.

## 1.3 Essay Three: Should Farm Input Subsidy Programs Target Poor or Non-poor Farmers?

The third essay provides guidance for the targeting of Malawi's farm input subsidy program (FISP). Specifically, the essay estimates the overall gain in yield for targeting non-poor farmers instead of poor farmers after accounting for the potential difference in input use efficiency and crowding out of commercial fertilizer by subsidized inputs across poverty groups. Poverty is measured in terms of both consumption expenditure and a wealth index computed from asset ownership and housing condition. Using consumption expenditure, households are classified into non-poor, poor and ultra-poor groups with the official poverty and ultra-poverty lines of MKW 85852 and MKW 53262 per capita per year respectively. Following Filmer and Pritchett (2001) and Dzanku (2015), households in the top 60% of the distribution of the wealth index are classified as non-poor, and those in the bottom 40% are classified as poor. Using the same logic, households in the bottom 16% are classified as ultra-poor.

The difference in input use efficiency is estimated with a multilevel model of maize production, while the difference in the crowding out is estimated using a double hurdle model of demand for commercial fertilizer. The steps involved in the empirical approach helps to clarify issues such as whether or not the poverty and food security goals of FISP can be achieved together by targeting poor farmers, whether or not poor farmers are as productive as non-poor farmers, and whether or not crowding out varies significantly across poor and non-poor farmers. By addressing these issues, the study adds to the targeting literature by providing an empirical standpoint for the targeting debate that has in the past been based mostly on anecdotal evidence.

The results indicate that non-poor farmers tend to use fertilizer more efficiently than poor and ultra-poor farmers, but crowding out of commercial fertilizer by subsidized fertilizer also tends to be significantly higher among non-poor farmers. The results therefore suggest a trade-off between targeting non-poor farmers and targeting poor farmers. A further analysis of the trade-off reveals that, the overall net gain in yield for targeting non-poor and farmers instead of their poor counterparts ranges from 3.1kg and

4.3kg per kilogram of nitrogen. Comparing non-poor to ultra-poor farmers, the overall gain in yield for targeting non-poor farmers instead of their ultra-poor counterparts ranges from 4.2kg and 6.4kg per kilogram of nitrogen respectively.

The results of this essay lead to two policy recommendations for the targeting of FISP. First, because poor farmers are less efficient in the use of inorganic fertilizer compared to non-poor farmers, simultaneously achieving the twin goals of the poverty reduction and food security goals of FISP will be difficult. As such it is recommended that FISP be focused either on the poverty reduction objective or the food security objective, but not both. Second, the study recommended that the FISP should be targeted at non-poor farmers if the goal is to promote food security at the household and national levels.

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# CHAPTER 2: MICRO-LEVEL WELFARE IMPACTS OF AGRICULTURAL PRODUCTIVITY

## 2.1 Introduction

*"Most of the world's poor people earn their living from agriculture, so if we knew the economics of agriculture, we would know much of the economics of being poor"*

*(Shultz, 1979)*

Poverty and food insecurity remain major developmental challenges in Sub-Sahara Africa (SSA) despite the significant progress that has been made over the past three decades. Current estimates indicate that SSA has the highest rates of poverty and undernourishment in the world – about 46.8% of the population of SSA live on less than $1.25 a day; 78% live on less than $2.5 a day; and about 23.2% (220 million people in absolute terms) are undernourished (FAO, IFAD and WFP, 2015; World Bank, 2011). Although the Millennium Development Goal (MDG) of halving extreme poverty by the end of 2015 has been achieved in the world as a whole, it is yet to be achieved in SSA where the extreme poverty rate has been reduced by only a quarter (FAO, IFAD and WFP, 2015; World Bank, 2011). The MDG of reducing hunger by half and the World Food Summit (WFS) target of reducing the number of undernourished people by half are also yet to be achieved in SSA (FAO 2015). Many development projects implemented by governments of SSA countries and their development partners have therefore prioritized poverty reduction and food insecurity, particularly in rural areas where majority of the poor and food insecure are located.

By virtue of the fact that majority of the poor (75%) and food insecure in SSA live in rural areas and mainly depend either directly or indirectly on agriculture for livelihood, it is widely recognized that agriculture is a major channel through which poverty and food insecurity can be reduced in the sub-region (IFAD, 2010; Ehui and Pender, 2005). This notion is perhaps also based on the historical evidence that agriculture played an integral role in the marked success achieved in poverty reduction in Asia, and the evidence that growth in agriculture tend to be more beneficial to the poor than growth in other sectors of developing economies (DFID 2004).

To date there has been major debates but little empirical evidence on this subject in SSA. This study provides such evidence by estimating the degree to which growth in agricultural productivity can affect the welfare of rural, agricultural households using nationally representative panel data from Malawi. Specifically, the study examines the impact that increases in agricultural productivity can potentially have on various measures of poverty and food insecurity of rural agricultural households. The measures of poverty considered include annual per capita consumption expenditure, relative deprivation in terms of consumption expenditure, poverty gap and severity of poverty; and the measures of food security include caloric intake from all sources of food, and relative deprivation in terms of caloric intake. Relative deprivation of a given household measures how consumption expenditure or caloric intake of that household compare to the mean consumption expenditure or caloric intake of households that are better off than the household in question (Stark and Taylor's (1989). Poverty gap and severity of poverty measure how far a given household is from the poverty line, with the latter being the square of the former (Foster et al., 1984). A detailed description of all the welfare measures are provided in section 1.4.2. The study focuses on rural agricultural households because they represent the segment of the SSA population for which agriculture-led, welfare-improving initiatives matter most.

Malawi makes an interesting case study. Malawi is one of the poorest countries in the world (ranked 174 out of 187 countries in terms of Human Development Index (UNDP 2014)). As in almost all SSA countries, poverty and food insecurity in Malawi are disproportionally rural phenomena; and majority of the country's poor derive their livelihood from agriculture. In an effort to curb poverty and promote food security, the government of Malawi has focused on increasing micro-level agricultural productivity by implementing a large scale Farm Input Subsidy Program (FISP). Since its inception in the 2005/2006 agricultural year, FISP has been the most well-known of its kind in Africa, and many governments of SSA countries have followed its example.

There are several pathways through which increases in agricultural productivity can potentially affect the welfare of agricultural households. The first is through the *"food and income"* pathway. Increases in farm output per hectare can have the direct effect of increasing the availability of food and household income. De Janvry and Sadoulet (1996), Acharya and Sophal (2002) and Hazell and Ramasamy (1991) provide evidence of the *"food and income"* pathway effect in Asia. De Janvry and Sadoulet (1996) observe that a percentage increase in total factor productivity would result in a 0.5% increase in the income levels of smallholder farmers in Asia. In Cambodia, Acharya and Sophal (2002) find that a percentage increase in rice yield would increase the income of smallholder farmers by 0.88% and 0.44% in the dry and wet seasons respectively. Similar observations are made by Hazell and Ramasamy (1991) in South India.

Agriculture can also affect the welfare of households indirectly through the "*wage*" pathway. Agricultural expansion usually increases land under cultivation, intensity of cultivation and/or the frequency of cropping, which in turn increase the demand for hired farm labor (Hayami and Ruttan, 1985; Lipton and Longhurst, 1989; Irz et al., 2010). The rising demand for hired farm labor drives up wages. Since hired farm labor is usually supplied by poor households, the increase in wages is likely to increase the income levels of poor households, and thus improve their welfare. In India, Datt and Ravallion (1998) find that higher real wages resulting from increases in agricultural productivity helped reduce absolute poverty levels. Also in India, Saxena and Farrington (2003) reports that agricultural labor wages rose by 3% per annum following increase in agricultural productivity between the 1970s and 1980s. Shively and Pagiola also observed that increases in crop intensity resulting from irrigation, increases annual labor use by 50% in the Philippines (2004).

The *"food price"* pathway is yet another indirect channel through which improvement in agricultural productivity can affect the welfare of households. Increases in agricultural output can drive down food prices. Because most poor households in developing countries are net food buyers and spend a substantial part of their income on food, the reduction in food prices will improve the poverty and food security status of households. A negative relationship between per capita food production and the prices of staples have been observed in many SSA countries including Ghana, Ethiopia, Burkina

Faso, Mali, and Sudan (Schneider and Gugerty, 2011). Otsuka (2000) and Biswanger and Quinzon (1986) observe that much of the Green Revolution's impact on inequality and poverty in Asia resulted from lower food prices accruing from output expansion. Schuh (2000) also suggests that the greatest achievement of world agriculture in the fight against poverty came via the supply of affordable food to the masses. Datt and Ravallion (1998) indicated that absolute poverty levels can be largely impacted by even smaller changes in food prices. It should however be noted that, since the demand for food is generally inelastic and markets are typically thin, large productivity increases could lead to a price collapse prices in staple food markets and eventually undermine incentives to produce, thereby hurting poor net food producers (Schneider and Gugerty, 2011). In addition, depending on the elasticity of demand for staple foods, the overall effect via the *"food price"* pathway depends on the tradability of agricultural products. When agricultural produce are non-tradable, productivity gains will increase aggregate food supply which will in turn drive down staple food prices (World Bank, 2007; Thirstle et al. 2001; Schneider and Gugerty, 2011).

Improvements in agricultural productivity also indirectly affect the welfare of households through the "*non-farm sector"* pathway. Growth in agricultural productivity could provide raw material for the non-farm sector; and the increase in income that result from increases in agricultural productivity could increase the demand for goods and services produced in the non-farm sector. These will in turn stimulate employment in the non-farm sector through both forward and backward linkages and eventually increase off-farm income of households (Hanmer and Naschold, 2000; Mellor, 1999). Empirical evidence backs the importance of the "*non-farm sector"* pathway. In an analysis of the

Kenyan economy, Timmer (2003) observed that the growth rate of the non-agricultural sector depended strongly on agricultural growth between 1987 and 2001. He indicates that non-agricultural growth increased by 30% and by 10% of the agricultural growth in the same year and in the previous year respectively. Delgado et al. (1998) reports that a dollar increase in farm income results in a \$0.96 and \$1.88 increase in income elsewhere in the Nigerien and Burkinabe economies respectively. In Zambia, Hazell and Hojjati (1995) observes that a dollar increase in farm income generates a further \$1.50 of income outside the agricultural sector. In Asia, a dollar increase in farm income creates \$0.8 non-farm income (Bell et al 1982; Hazell and Ramaswamy, 1991). Similar observations were made by Stern (1996) for several other developing countries between 1965 and 1980.

This study adds to the development economics literature by providing an SSA micro-level context to the existing literature on the welfare impacts of growth in agricultural productivity. Most of the empirical evidence on the subject are either at the macro-level (Diao et al. 2010; Ravallion, 2009; Breisinger, et al. 2009; De Janvry and Sadoulet, 2002 and 2010) or meso-level (Ravallion & Datt, 2002; Datt & Ravallion, 1998a, 1998b, Foster & Rosenzweig, 2004). To the best of my knowledge, Dzanku (2015) and Sarris et al. (2006) are the only studies that have addressed the micro-level welfare impacts of agricultural productivity in SSA. These studies are improved upon and extended in a number of ways. First, and perhaps most importantly, this study extends the measures of household welfare used in the previous studies beyond the "*incidence measures"* of welfare – measures (monetary or non-monetary) such as per capita consumption expenditure, whether or not a household is poor etc. that do not directly compare the welfare of households to that of other households or to a predetermined level of welfare – to include relative deprivation, poverty gap and severity of both poverty. In addition to knowing the effect of agricultural productivity on the level of household welfare, it is important to also understand the extent to which growth in agricultural productivity affect household welfare relative to the welfare of other households and a pre-determined level of welfare (usually the poverty line). Measuring welfare in terms of relative deprivation, poverty gap and severity of poverty provides such understanding.

Second, the study extends the work of Dzanku (2015) and Sarris et al. (2006) by conducting a simulation analysis to estimate how incremental changes in agricultural productivity affect poverty and ultra-poverty rates as well as the number of people who can potentially be lifted out of poverty and ultra-poverty. Third, the study controls for farm-wage income and income from off-farm economic activities that Dzanku (2015) and Sarris et al. (2006) could not control for. A substantial proportion of rural agricultural households engage in off-farm income generating activities and most of them are net suppliers of labor in the agricultural labor market. Hence the absence of these variables from welfare models of rural, agricultural households could potentially result in omitted variable bias, thereby rendering the estimates of the effect of agricultural productivity on welfare inconsistent. Fourth, Dzanku (2015) and Sarris et al. (2006) treated agricultural productivity as endogenous in their welfare models citing the possibility of omitted time-varying factors, but this study shows that bias resulting from omitted time-varying factors is not necessarily present in productivity-welfare models. This is done by using an approach developed by Oster (2015) and a formal test of endogeneity (via the control function approach). Lastly, this study uses nationally representative panel data for the analyses. Sarris et al. (2006) was based on a cross-sectional data from two (Kilimanjaro and Ruvuma) of the thirty regions of Tanzania while Dzanku (2015) was used a panel data from eight villages in two (Eastern and Upper East) of the ten regions of Ghana.

Results from this study indicate that growth in agricultural productivity has the expected significantly positive effect on the welfare of rural agricultural households. The elasticity of per capita consumption expenditure with respect to maize yield and value of crop per hectare is 0.13 and 0.10 respectively; and the corresponding elasticity for per capita caloric intake is 0.06 and 0.05 respectively. The relativity, depth and severity of poverty and food insecurity also have the expected inverse relationship with agricultural productivity. The simulation analysis indicates that a 50% increase in maize yield will decrease the micro-level poverty and ultra-poverty rates by 6.7 and 2.5 percentage points respectively. The simulation results further indicate that, if all farmers produce at their full potential, over 25% of rural agricultural households will still be poor. Thus, although growth in agricultural productivity has the expected welfare-improving effect, the magnitude of the effect is small relative to the emphasis that has been placed on increasing agricultural productivity in terms of poverty reduction and the promotion of food security.

## 2.2 Background: Agriculture, Poverty and Food Insecurity in Malawi

Despite development in other sectors of the economy, similar to many other countries in SSA, agriculture continues to be the most important sector of Malawi's economy and an essential part of its social fabric. The sector accounts for approximately 30 percent of gross domestic product (GDP), employs over 85 percent of households, and serves as the main foreign exchange earner (60 percent for tobacco alone in 2014). With about 74 percent of all rural income accounted for by crop production, agriculture is also the main source of livelihood for poor and rural households (Chirwa et al., 2008)[2]. The low share of agriculture in GDP relative to the large population and labor force employed in the sector proves that most people remain locked in low-productivity, subsistence agriculture. In other words, progress in transitioning smallholders from subsistence to commercial production, or out of agriculture altogether, has been limited.

Malawi's agricultural sector is made up of smallholder and estate farms. Smallholder farms account for 70 percent of the 2.5 million hectares of the country's arable land under cultivation but the average smallholder farm is approximately one hectare (MoAFS 2012). Although smallholder farmers produce substantial amounts of cash crops including tobacco, tea, and cotton, these farmers cultivate mainly maize, the main staple crop of Malawi, and other food crops such as rice, legumes and pulses for subsistence purposes. Majority of the smallholder farmers are net food buyers because their seasonal food production falls short of their food requirements. In contrast to the smallholder farms, estate farms have a minimum size of approximately 10 ha. They produce mainly tobacco, sugar, tea and other cash crops almost entirely for export. While estate farms usually occupy leasehold or freehold land, the land for smallholder farms is predominantly under customary tenure system where households have cultivation rights but no formal title to the land.

Over the last two decades, agricultural productivity, as measured by maize yields has been erratic. Factors that are commonly cited as underlying the trend in agricultural

[2] The GDP contribution of agriculture is the average of 2010 to 2013, computed with data obtained from the Reserve Bank of Malawi. The contribution of agriculture to foreign exchange earnings refers to 2014, as reported by Mwanakatwe (2014). The contribution of agriculture to employment is for 2010 and 2013 based on the IHS3 (Third Integrated Household Survey) and IHPS (Integrated Household Panel Survey) datasets.

productivity include weather variability (as Malawian agriculture is almost entirely rainfed), declining soil fertility, limited use of improved agricultural technologies and sustainable land management practices, rationed agricultural extension services, market failures, and underdeveloped and poorly maintained infrastructure (World Bank 2007). The already modest increase in productivity is further undermined by population growth (MoAFS, 2010). That notwithstanding, the Ministry of Agriculture and Food Security (2010) estimates that the country's yield gap – the difference between potential yield and the actual yield of the average farmer – ranges from 38-53% for cereals, and 40-75% for legumes (Lobell et al., 2009). This implies that there is substantial room for productivity improvements. Given the rural nature of the country and the fact that poor households are predominantly farmers, improvements in agricultural productivity, if fully exploited could have direct implications for living standards.

Poverty in Malawi remains widespread. Estimates from the Third Integrated Household Survey (IHS3) indicate that 50.7% of the population is poor and 24.5% is ultra-poor; and the poverty and ultra-poverty gaps are 18.9% and 7% respectively[3]. Using the international poverty lines based on purchasing power parities of $1.25 and $1.90 a day, the poverty rate for Malawi was 61.6% and 70.9% respectively in 2010 (World Bank, 2011). These figures classify Malawi along with countries such as Burundi and Madagascar among the poorest countries in SSA and the world as a whole. Malawi's headcount poverty barely dropped between 2004 and 2011, but countries such as Rwanda

[3] Households are classified into poor and ultra-poor groups using the official poverty and ultra-poverty lines of MKW 85852 and MKW 53262 per capita per year respectively; and poverty gap is as defined in section 2.1.

and Tanzania that had higher poverty rates and those with lower poverty rates like Ghana, Ethiopia and Uganda recorded considerable reductions in poverty.

As in many other developing countries, poverty in Malawi is disproportionally a rural phenomenon. Between 2004/2005 and 2010/2011, although national poverty rates were high and decreased only slightly, poverty and ultra-poverty in urban areas fell significantly from 24.5% to 17.3% and from 7.5% to 4.3% respectively (de la Fuente and Cumpa, 2015). The poverty gap and severity of poverty in the urban areas also fell significantly from 7.1 to 4.8 percentage points and from 2.8 to 2.0 percentage points respectively between 2004 and 2011 (de la Fuente and Cumpa, 2015)[4]. In rural Malawi however, poverty stagnated at about 56% between 2004/2005 and 2010/2011, and ultra-poverty rate increased significantly from 24.2% to 28.1% over the same period (de la Fuente and Cumpa, 2015). Poverty gap and severity of poverty and ultra-poverty also worsened in rural Malawi between 2004 and 2011.

Like poverty, food insecurity, is prevalent and a rural phenomenon in Malawi. Nationally, the caloric intake of over 50% of the population falls short of the minimum daily caloric requirement of 2,100 calories per day between 2004 and 2013 (Seff and Jolliffe, 2015). In fact the proportion of the undernourished population increased slightly from 50% in 2004 to 51% in 2013. Child malnutrition is also high in Malawi. Using the Demographic Heathy Survey (DHS), Seff and Jolliffe (2015) reports that the rate of stunting was 47.8% in 2013, about 5 percentage point decrease from the 2004 value. The percentage of underweight children dropped from 18.6% to 14.1% between 2004 and 2010 while the prevalence of wasting fell from 6.2 to 4.1 over the same period.

[4] Poverty gap and severity of poverty are as defined in section 2.1.

Unsurprisingly, like poverty, undernourishment is disproportionally higher in the rural areas than it is in the urban parts of the country. In 2013 for instance, undernourishment in the rural Malawi was 53%, about 11 percentage points higher than the corresponding value in urban areas (Seff and Jolliffe, 2015).

As in many agrarian developing countries, poverty reduction and improvement in other measures of welfare in Malawi have been identified to be closely linked to the performance of the agricultural sector. Chirwa et al. (2013) observes that between 1990 and 2005, the agricultural sector grew by only 6.8% per annum, causing poverty to fall by just 0.2% per annum. Because of this close relationship between the performance of the agricultural sector and poverty; and the fact that poverty is predominantly rural and most of the rural households are farmers, most of the pro-poor development strategies in Malawi have focused on promoting growth in the agricultural sector. Notable among these programs is the Farm Input Subsidy Program (FISP) which the government is currently implementing. FISP was introduced in the 2005/2006 agricultural year and has since been the nation's main agricultural policy intervention in terms of government expenditure. FISP officially targets poor and vulnerable farmers with the primary goal of increasing food production in order to ensure household food security, national food sufficiency, and also reduce poverty by increasing the income levels of beneficiaries (Chirwa and Dorward, 2010). The program currently provides inorganic fertilizers and improved maize and legume seeds to over 50% of rural, smallholder farmers at highly (about 95%) subsidized prices (Kilic et al. 2013). Each beneficiary is entitled to 50kg of Urea; 50kg of NPK 23:21:0; 5kg of improved maize seed or 10kg of open pollinated variety maize seed; and a kilogram of legume seed (Kilic et al. 2013).

## 2.3 Conceptual Framework

The effect of agricultural productivity on the welfare of rural agricultural households is conceptualized using the utility maximization framework. Consider the utility function, $U(q, L)$, of a rural agricultural household defined over the consumption of a vector of goods, $q$, and a vector of labor variables, $L$. The vector of labor variables is made up of four components: labor allocated to farm activities $(L_f)$, labor allocated to off-farm income-generating activities $(L_{of})$, labor supplied to other households $(L_s)$, and labor allocated to leisure $(L_l)$. It is assumed that rural agricultural households maximize their utility subject to their budget constraints by choosing optimal levels of consumption and leisure. Following Christiaensen and Demery (2006), in order to estimate the effect of agricultural productivity on the welfare of rural agricultural households, the indirect utility function of a rural agricultural households is defined as:

$$V(p, w, A) = \max_{q,L}[u(q, L)|\pi(p, w, A, B) + wL = p.q] \qquad (2.1)$$

where $\pi(p, w, A, B)$ is the profit obtained from all (farm and off-farm) household enterprises, and depends on $p$ (a vectors of prices for goods q), $w$ (vector of wage rates), $A$ (agricultural productivity) and $B$ (productivity of off-farm income-generating activities). $\pi(p, w, A, B)$ is defined as:

$$\pi(p, w, A, B) = \max_{L_f, L_{of}}[pQ - w(L_f + L_{of})|(Q_f = Af(L_f, X_f, H, G);\ Q_{of} = Bf(L_{of}, X_{of}, H, G)] \qquad (2.2a)$$

$$Q = Q_f + Q_{of} \qquad (2.2b)$$

where $Q_f$ and $Q_{of}$ are quantities of farm and off-farm outputs respectively; $X_f$ is a vector of variables such as land that are required for farm production; $X_{of}$ is a vector of variables other than labor that are required for off-farm production; $H$ is a vector of household characteristics such as household size, gender of household head etc.; and $G$ is a vector of household geo-variables such as distance to market, distance to district capital, access to road, agro-ecological zone etc. Households choose the optimal levels of farm and off-farm labor $(L_f, and\ L_{of})$ to maximize profits, and then subsequently choose $q$ and $L$ to maximize utility. Rural agricultural households are assumed to be price takers in both labor and output markets.

Taking the total differential of equation (2.2a) and applying the envelop theorem, the change in welfare resulting from a unit increase in agricultural productivity, $A$, is given by:

$$\alpha = \frac{dV}{\varphi dA} = [Q - q]\frac{dp}{dA} + [L - (L_f + L_{of})]\frac{dw}{dA} + p\frac{dQ}{dA} \tag{2.3}$$

where $\varphi$ is the marginal utility of income; $[Q - q]$ is the difference between what the household produces and what it consumes; $\frac{dp}{dA}$ is the change in (food) prices resulting a unit increase in agricultural productivity; $\frac{dw}{dA}$ is the change in agricultural wage resulting from the change in agricultural productivity; and $p\frac{dQ}{dA}$ is the monetary value resulting from a change in output caused by the change in agricultural productivity.

Equation (2.3) shows that the effect of agricultural productivity on household welfare depends on the direct effect of agricultural productivity on overall output $(\frac{dQ}{dA})$; the degree to which agricultural productivity affects the prices of consumable goods; and status of households (net seller, net buyer or autarkic) in the output and labor markets. All things being equal, aggregate supply of agricultural output and demand for hired labor for agricultural production will both increase with increases in household level agricultural productivity, thus $\frac{dp}{dA}$ is expected to be negative and $\frac{dw}{dA}$ to be positive. Because most rural agricultural households are net buyers in the food market (i.e. $Q < q$) and either net sellers or autarkic in the labor market [i.e. $L \geq (L_f + L_{of})$], an increase in agricultural productivity is expected to have an overall positive effect on the welfare of rural agricultural households, i.e. $\alpha > 0$.

Given equations (2.1) to (2.3), the conceptual model for the effect of agricultural productivity on the welfare of rural agricultural households is specified as:

$$W = f(A, Y, p, w, H, G) \tag{2.4}$$

where *Y* is a vector of other sources of income to the households, and the other variables are as defined above.

## 2.4 Estimation Strategy

In order to estimate the extent to which a change in agricultural productivity affects the welfare of rural agricultural households, the conceptual model in equation (2.4) is specified generally as:

$$W_{it} = \alpha A_{it} + \boldsymbol{X}_{it}\,\beta + \boldsymbol{H}_{it}\gamma + \boldsymbol{P}_{it}\delta + \boldsymbol{G}_{it}\tau + \varepsilon_{ij} \qquad (2.5a)$$

$$\varepsilon_{ij} = c_i + \mu_{it} \qquad (2.5b)$$

where *i* and *t* indexes household and time respectively; $W_{it}$ is household welfare; $A_{it}$ is household-level agricultural productivity; $\boldsymbol{X}_{it}$ is a vector of variables measuring other sources of household income such as agricultural wage income, and non-farm income;

$H_i$ is a vector of household characteristics, such as household size, landholding in hectares, and highest education achieved by a member of the household; $P_{it}$ is a vector of prices including commercial price of urea fertilizer, and a spatial food commodity price index; $G_{it}$ is a vector of household geo-variables such as distance to road, and agro-ecological zone; and $\varepsilon_{ij}$ is the stochastic error term. The variables making up each of the vectors are defined in table 2.1. $\alpha$, $\beta$, $\gamma$, $\delta$, *and* $\tau$ are parameters, with $\alpha$ being the parameter of interest - the effect of agricultural productivity on household welfare. The error term, $\varepsilon_{ij}$, is made of two components – unobserved time-invariant factors $c_i$ (also called unobserved heterogeneity); and unobserved time-varying factors $\mu_{it}$, that affect the welfare of households. The unobserved time-invariant factors include such factors as household's risk aversion and management ability, and the time-varying factors include such variables as household's health status, political turmoil etc.

### 2.4.1 Potential endogeneity of agricultural productivity in welfare model

In order to obtain consistent estimates of the effect of agricultural productivity on the welfare of households, the correlation between the observed covariates in equation (2.5a) and the unobserved time-invariant and time-varying factors must be controlled for. Because the data used in the analyses is panel, household fixed effects and the Mundlak-Chamberlain (MC) device are used to control for unobserved heterogeneity in the models depending on the welfare measure. The MC device is implemented by including a vector of variables that consist of means of all time-varying covariates in equation (2.5a) for household $i$, allowing the unobserved heterogeneity to be correlated with the observed covariates (Mundlak 1978, and Chamberlain 1982).

Even after controlling for unobserved heterogeneity, the estimate of the effect of agricultural productivity on welfare will still be inconsistent if $A_{it}$ is correlated with $\mu_{it}$, unobserved time-varying factors. The correlation between $A_{it}$ and $\mu_{it}$ could potentially come from three sources: omitted variable bias, errors in the measurement of agricultural productivity, and reverse causality between agricultural productivity and welfare. Plots size was measured using GPS estimates, so the study is confident that agricultural productivity is measured with little or no errors. Reverse causation is avoided by ensuring that the survey instrument was administered after harvesting of agricultural products was completed. Hence the direction of the effect will be agricultural productivity on welfare rather than vice versa.

Omitted variable bias however could be a problem since welfare and agricultural productivity are both likely to be affected by the health status of households, and unobserved institutional and location factors (Keswell, Burns and Thornton, 2012; Dzanku 2015). The robustness of the estimates to omitted variables bias resulting from unobserved time-varying factors was assessed using an approach developed by Oster (2015). Based on the assumption that observables and unobservables have the same explanatory power in explaining the dependent variable, Oster (2015) demonstrates that the "*controlled estimate*" (the coefficient on the variable of interest from the model with the full set of observable controls) and the "*bias-adjusted estimate*" (the coefficient on the variable of interest after controlling for both observables and unobservables) provide a useful range that can be used to examine the robustness of the "*controlled estimate*" to omitted variable bias. The "*controlled estimate*" is robust to omitted variable bias if the range does not contain zero and is within the confidence interval of the "*controlled* *estimate*". The Oster (2015) approach considers not only coefficient movements but also movements in R-squared values when including additional independent variables. The *"bias-adjusted estimate"* is calculated as:

$$\beta^{*} = \beta^{c} - (\beta^{uc} - \beta^{c}) * \frac{R_{max} - R^{c}}{R^{c} - R^{uc}} \tag{2.6}$$

where $\beta^{c}$ and $R^{c}$ are the "*controlled estimate*" and the $R^2$ of the regression from which the "*controlled estimate*" was obtained respectively; and $\beta^{uc}$ and $R^{uc}$ are respectively the coefficient estimate and $R^2$ of the uncontrolled regression, the regression in which the variable of interest is the only independent variable. $R_{max}$ is the $R^2$ of a hypothetical regression in which both observables and unobservables are controlled for, which is clearly unknown. Oster (2015) suggests that $R_{max} = \min\{2.2R^{c}, 1\}$. The $R^{c}$ from the models are such that $2.2R^{c} > 1$, suggesting the choice of $R_{max} = 1$ based on Oster (2015). Meanwhile Gonzalez and Miguel (2015) argues that $R_{max}$ of 1 or close to 1 is likely to be too high for poverty analyses in developing countries where consumption and income levels are measured with considerable level of error. Based on relatively high quality US data, Gonzalez and Miguel (2015) suggested that $R_{max}$ should not be greater than 0.9. An $R_{max}$ of 0.89 was therefore chosen for the analyses in this study.

The control function approach is also used to formally test for the potential endogeneity of agricultural productivity in the welfare models (Wooldridge, 2010). This is done in order to consider the possibility of the underlying assumption of Oster (2015) not holding, and also to consider other potential sources of endogeneity. The control function approach in this case involves taking the residuals from a reduced form model of agricultural productivity and including them as an independent variable in the structural welfare model equation (2.5a) (Wooldridge, 2010). The significance or otherwise of the coefficient on the residuals provides a test of endogeneity of agricultural productivity (Wooldridge, 2010). The control function approach requires the inclusion of instrumental variables(s) in the reduced form model of agricultural productivity. The study uses the duration (days) of the photosynthetic period over the growing season as our instrumental variable. This variable is highly correlated with agricultural productivity, and apart from agricultural crop yield, this study is not aware of any other channel(s) through which it can affect the welfare of rural agricultural households.

## 2.5 Data and Sample Selection

The analyses in this study is based on Malawi's Integrated Household Panel Survey (IHPS) data. IHPS is a two-wave panel dataset collected by the National Statistical Office of Malawi (NSO) with support from the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) program. The survey for the first wave of the dataset covered 3247 households (hereafter baseline households) in the 2009/2010 agricultural year. The sampling was representative at the national, regional and urban/rural levels. Apart from the island district of Likoma, the survey covered all the districts in the three regions (Northern, Central and Southern) of the country. The three regions were segregated into urban and rural strata, with the urban strata consisting of Lilongwe City, Blantyre City, Mzuzu city and the Zomba municipality (NSO, 2012).

The survey for the second wave of the dataset was conducted in the 2012/2013 agricultural year and attempted to track and resample all the baseline households as well as individuals (projected to be at least 12 years) that split-off from the baseline households between 2010 and 2013 as long as they were neither guests nor servants and are still living in mainland Malawi. Once a split-off individual was located, the new household that he/she formed or joined was also brought into the second wave. In all, a total of 4000 households were traced back to 3104 baseline households. An overwhelming majority, 76.80%, of the 3104 baseline households did not split over time; 18.49 percent split into two households; and rest (4.70 percent) split into 3-6 households. Considering the 20 baseline household that died in their entirety between 2010 and 2013 and the fact that 4,000 households could be traced back to 3,104 baseline households, the dataset has an overall attrition rate of only 3.78 percent at the household level.

All non-agricultural households (580 and 845 households in the first and second waves respectively), as well as urban agricultural households (370 and 438 households in the first and second waves respectively) were dropped from the dataset. The urban agricultural households were dropped because farming in Malawi is predominantly rural. In order to avoid reverse causality in the welfare models, households for which questions about their food and non-food consumption were asked before the harvesting of agricultural products were also dropped. In the end a panel of 2,023 households, 946 households in the first wave and 1077 household in the second wave was used for the analyses. Although households were dropped, the remaining sample is nationally representative because as indicated earlier the survey design was such that selected households were representative of the rural and urban population.

Attrition bias could not be tested for in the data because there are no regression-based tests for attrition when fixed effects or MC devise models are used with a panel of only two wave. A panel of more than two-waves are required for such tests (Wooldridge, 2010; Mason and Smale, 2013). That notwithstanding, the study is confident that attrition bias is not likely to be a concern because as indicated earlier, the attrition rate is only 3.78 percent at the household level.

### 2.5.1 Measures of Welfare and Agricultural Productivity

Welfare is measured in terms of both poverty and food insecurity. The poverty measures of welfare include per capita annual consumption expenditure, relative deprivation in terms of per capita consumption expenditure, poverty gap and severity of poverty[5]. The annual consumption expenditure variable is an aggregate expenditure variable made up of expenditures on food, non-food, durable goods and housing. The food expenditure component was constructed by adding up expenditure on all food items consumed by the household at home and away from home over the past seven days. The food items consumed consisted of cereals, grains and cereal products; roots, tubers and plantain; nuts and pulses; vegetables; meat, fish and other animal products; fruits; cooked food from vendors; milk and milk products; sugars, fats and oils; beverages; and spices and miscellaneous. The non-food expenditure component consists of expenditure on utilities such as kerosene and electricity, health, transport, communications, recreation, education, furnishing, personal care etc. over a reference period. For instance, the reference period for expenses on public transport is the last seven, and expenses on mobile phones and personal care are collected for the last month. Payments of mortgages or debt,

[5] The study chooses per capita consumption expenditure instead of income as the primary measure of poverty because it is a more useful and accurate measure of living standards (World Bank, 2015)

repairs to dwelling and construction materials, losses to theft, remittances to other household members, and expenditures on marriage, dowries, births, and funeral were excluded in order to avoid overestimating the level of household welfare. The durable goods expenditure consists of the stream of services that households derive from all (non-production) durable goods possessed. The estimation of this component relies on information on the number of durable goods owned, their age, and their current value. It was assumed that the purchases of these goods are uniformly distributed over time. This assumption enables the study to estimate the average lifetime of each of the durables goods as two times their average age. The remaining time of the durable goods is then estimated as the difference between the current age and the expected lifetime, but replaced by the two years if the current age exceed the expected life time. Finally, the annual use value of each of the durable goods is calculated as the ratio of the current value to the remaining lifetime. The housing expenditure was obtained by measuring the flow of services received by dwelling in it. For households that dwell in rented houses, the value of the housing will be the rent paid.  For households that did not rent their dwellings, their housing expenditure is calculated as the amount of money that would be received if they were to rent out the dwelling. The eventual consumption expenditure was adjusted for temporal and spatial cost of living differences using monthly CPI and Laspeyres price index. In order to use a common reference period for all the components of expenditure, all the expenditures were scaled to their annual equivalent values. A more elaborate description of the construction of the consumption expenditure variable is provided in World Bank (2013).

Relative deprivation in terms of consumption expenditure is measured with Stark and Taylor's (1989) index, given by:

$$RD = AD(y_i) * P(y_i) \tag{2.7}$$

where $AD(y_i)$ is the mean per capita annual consumption expenditure of households in a reference group that are richer than household $i$, and $P(y_i)$ is the proportion represented by these households. The full sample was used as the reference group because the study is interested in estimating average nationally representative impacts. The greater the index is for a given household, the more deprived the household is relative to other households in terms of per capita consumption expenditure.

Poverty gap and severity of poverty are measured by Foster-Greer-Thorbecke index (Foster et al., 1984). The index is given by:

$$FGT_\alpha = \left(\frac{1}{n}\right)\sum_{i=1}^{h}\left(\frac{Z - y_i}{Z}\right)^\alpha \tag{2.8}$$

where $y_i$ is the per capita consumption expenditure of household $i$; and $Z$ is the official poverty line for Malawi (MKW 85852). FGT is typically a summary statistic, but following Mason and Smale (2013), it is made amenable for use in a regression model by constructing a household specific version of the index using the expression within the summation sign. $FGT_1$ (i.e $\alpha = 1)$ and $FGT_2$ (i.e. $\alpha = 2)$ represent poverty gap and severity of poverty respectively. Both poverty gap and severity of poverty take values of zero for non-poor households and a fraction for poor households, i.e. $\{FGT_1 = [0,1];\ FGT_1 = [0,1]\}$

The food security measures consist of per capita caloric intake and relative deprivation based on per capita caloric intake. Caloric intake is computed as the total amount of calories contained in all the food items consumed by the household at home and away-from-home within the past week. Relative deprivation in terms of per capita caloric intake is measured with equation (2.7) where, in this case, $AD(y_i)$ is the mean per capita caloric intake of households in a reference group that have higher caloric intake than household $i$, and $P(y_i)$ is the proportion represented by these households.

The study further generated a measure of welfare called *composite welfare* that combines households' poverty and food security status. *Composite welfare* is an ordered categorical variable defined as 1 for poor and food insecure households; 2 for non-poor but food insecure or poor but food secured households; and 3 for non-poor and food secured households.

Agricultural productivity is measured by maize yield and value of total crop output per hectare. Maize yield is considered because is maize the staple and the most widely cultivated crop in Malawi – it is cultivated by about 90% of farmers on 70% of their farm plots (NSO, 2013). Most households produce other crops in addition to maize. In order to account for the production of these other crops in the analyses, the study also measured agricultural productivity as the monetary value of all the crops produced per ha of land cultivated.

## 2.6 Choice of Estimators

Depending on the measure of welfare, the effect of agricultural expenditure on welfare is estimated with either a household fixed effects estimator, a two-part estimator, or a correlated-random effects (CRE) ordered probit estimator. The household fixed effects estimator is used when welfare is measured by per capita annual consumption expenditure, relative deprivation in terms of consumption expenditure, per capita caloric intake or relative deprivation in terms of per capita caloric intake because these models are linear. The two-part estimator is used when the measure of welfare is either poverty gap or poverty severity; and the CRE ordered probit estimator is used when welfare is measured by the composite measure[6]. The first part of the two-part estimator estimates the probability of being poor using a logit estimator while the second part estimates the extent of poverty conditional on being poor using the fractional logit estimator. The two-part estimator is used instead of a simple fractional estimator because the study views poverty and severity of poverty as corner solution outcomes – i.e.: takes values of zero for poor households and continuous (fraction) for non-poor households. Thus the two-part estimator accounts for the fact that there may be differences in how agricultural productivity affect the probability of being poor and how it affects the extent of poverty. The use of the two-part estimator also allows the study to account for the fact that the continuous part of poverty gap and severity of poverty are only observed for non-poor households.

## 2.7 Results

### 2.7.1 Descriptive Statistics

The descriptive statistics of the variables in the welfare models are presented in table 2.2. The statistics indicate that the poverty status of rural agricultural households in

[6] The two-part estimator is implemented using the *twopm* command in stata (Belotti, 2015). *twopm* has a variety of estimators that can be used for the first and second parts depending on research interest and the nature of the dependent variable. More importantly, marginal effects for the combine model can be easily recovered using the margins command when *twopm* is used.

Malawi improved significantly in all dimensions (level, relativity, depth and severity) between 2010 and 2013. Per capita consumption expenditure increased by about 11.68% between survey waves; relative deprivation in terms of consumption expenditure decreased by about 4.15% between waves; and poverty gap and severity of poverty decreased by 4 and 2 percentage points respectively.

The average per caloric intake was 2,450 Kcal in 2009/2010 agricultural year and 2,360 Kcal in the 2012/2013 agricultural year. Compared to the minimum nutritional requirement of 2400 Kcal per day, the average rural household in Malawi is barely food secured in 2010 and food insecure in 2013. Based on these figures, food insecurity tend to be more of a developmental challenge than poverty among rural agricultural households in Malawi.

Agricultural productivity increased among rural agricultural households between 2010 and 2013 on average, as the value of crops per hectare (in real terms) increased by 16.22% (from MKW 44440 to MKW 51650) and maize yield increased by 22.82% (from 1340kg/ha to 1650kg/ha). The significant increase in agricultural productivity could have been due to increased use of inorganic fertilizer and other physical inputs, as well as to farmers getting better at combining inputs in crop production.

Real income from other sources such as tree/permanent crop production, off-farm income and agricultural wage increased significantly between 2010 and 2013. The average rural agricultural household earned MKW 1490 from tree/permanent crop production, MKW 11170 from off-farm income generating activities, and MKW 19520 from working on other farmers' farms; and these increased significantly to MKW 3030, MKW 32200 and MKW 31390 respectively in 2013. The increase in agricultural productivity and income from other sources likely contributed to the improvement in the poverty status of households.

About 74% of the households are headed by males in both years, and the average age of household heads is about 44 years. The number of years of education of the most educated person in the household is about 7 years on average. Given the importance of education to poverty reduction, the low level of education among rural agricultural households might help explain why poverty is widespread in Malawi. The average household size increases significantly from 5.08 to 5.23. The average dependency ratio is about 125%; indicating that on average, there are more dependents than there are active working people in rural agricultural households. All things being equal, the high dependency ratio will have implications for the welfare of the households.

Ownership of agricultural assets is very low among rural agricultural households. The average household owns less than a hectare of land (0.74ha in 2010 and 0.82ha in 2013) and less than 20% of them own crop storage structures. Since rural farmers derive their livelihood mainly from crop production, the small landholdings and limited access to crop storage structures have implications for their welfare. The small landholding curtail farmers' income levels by limiting the quantity of crops that they can produce and by rendering most of them net buyers of food that could have been otherwise produced. The lack of crop storage structures further exacerbates income levels by compelling most rural farmers to sell their produce at (or a few months after) harvest where prices of agricultural produce are usually low.

On average, only 10% of households had access to credit in 2010 but this increased significantly to 23% in 2013. Agricultural extension for crop production was accessed by 53% and 66% of households in 2010 and 2013 respectively. Although access to credit and extension increased over time, there is need for a more widespread access to these services because of their potential positive impact on agricultural productivity and consequently on welfare of rural households.

### 2.7.2 Empirical Results

Table 2.3 presents a summary of the results of the impact of agricultural productivity on the various measures of household welfare. The full model results are presented in appendix A (tables 2.A1 to 2.A6)[7]. The last column of table 2.3 shows the range of the estimates based on Oster (2015). Because the range of estimates do not contain zero and the upper bounds are within the confidence interval of the "*controlled estimates*", the study is confident that the estimates are robust to omitted variable bias (Oster 2015, Nghiem et al., 2015; Freier et al, 2015; Gonzalez and Miguel, 2015). The formal test of endogeneity using the control function approach also rejects the hypothesis that agricultural productivity is endogeneous in our welfare models. Hence, overall, estimates are robust to not only omitted variable bias but also other potential sources of endogeneity. Results of the endogeneity test using the control function approach are reported in tables 2.A7 and 2.A8 in the appendix A.

#### 2.7.2.1 Effect of Agricultural Productivity on Welfare

The results indicate that agricultural productivity has the expected, significant inverse relationship with all the measures of poverty (table 2.3, 2.A1 and 2.A3). A

[7] The Stata codes used in generating the results are presented Appendix C.

percentage increase in maize yield and the value of crops per ha will increase per capita consumption expenditure by 0.132% and 0.096% respectively; reduce relative deprivation in terms of consumption expenditure by 0.058% and 0.042% respectively; reduce the poverty gap by 0.034 and 0.019 percentage points respectively; and reduce the severity of poverty by 0.017 and 0.008 percentage points respectively.

The direction of the effect of agricultural productivity on the poverty measures of welfare supports the widely held notion that improvement in agricultural productivity could be an effective channel for improvement in the welfare of rural agricultural households in Malawi. However, given the emphasis that has been placed on agriculture in terms of poverty reduction in Malawi, the magnitude of the effect is substantially lower than one might initially expect.

The inverse but small effect of agricultural productivity on poverty is also reflected in its effect on poverty rate and the number of people that can be lifted out of poverty (table 2.4). The simulation results indicate that a 50% increase in maize yield, from the current level of 1340kg/ha, will reduce the poverty (ultra-poverty) rate among rural agricultural households by 6.77 (2.54) percentage points from 40.78% (11%) to 34.01% (8.46%). The 50% increase in maize yield will correspondingly lift about 622,015 people out of poverty and 281,718 people out of ultra-poverty. The estimates also show that a 100% increase in maize yield will decrease the poverty (ultra-poverty) rate to 33.03% (7.46%) respectively; and lift 662,994 people out of poverty and 325,018 people out of ultra-poverty. The simulation results further show that 25.32% of rural agricultural households will still be poor, (and 5.14% be ultra-poor) even if all households produce maize at full potential, where full potential level of maize production is defined in this study as the highest household-level maize yield in the district reported in our sample. Table 2.4 also show that the reduction in poverty rate and the number of people lifted out of poverty appear to stagnate at around a 50% increase in agricultural productivity. This is because the consumption expenditure of the remaining households are so far below the poverty line that further increases in productivity are not enough to move them above the poverty line.

Similar significant but small effect of agricultural productivity on measure of poverty have been observed in other parts of Sub-Sahara Africa. Using the instrumental variable estimator and controlling for household fixed effects, Dzanku (2015) observed that a percentage increase in value of output per ha will increase per capita consumption expenditure by 0.207% all things being equal. In Tanzania, Sarris et al. (2006) estimate (using cross-sectional data and an instrumental variable estimator) the elasticity of per capita consumption expenditure with respect to agricultural productivity (value of output per ha) to be 0.15 and 0.54 for rural households in the Kilimanjaro and Ruvuma regions respectively. The authors further observed that poverty rate will reduce by 6 percentage points in Kilimanjaro and 19 percentage points in Ruvuma if all poor households were to produce at least the median level of agricultural productivity of the whole sample.

Agricultural productivity also has the expected, significantly inverse relationship with food insecurity and the composite measure of welfare (tables 2.3, 2.A2, 2.A4, 2.A5 and 2.A6); but, as in the case of poverty, the magnitude of the effect is quite small. A percentage increase in maize yield and value of crops per hectare will, all things being equal, increase caloric intake by 0.06% and 0.054% respectively. For the composite measure of welfare, the estimates indicate that a percentage increase in maize yield and value of crops per ha will decrease the probability of being poor and food insecure by 0.057% and 0.043% respectively; and increase the probability of non-poor and food secure 0.060% and 0.046% respectively.

Where do the findings of this study fit in the broader discourse of the potential role of agriculture in improving the welfare of households in SSA; and how does it contribute to or advance the discourse? This study points to an important aspect of the welfare-improving role of agriculture that is worth attention. It reveals that agriculture cannot bring about the needed improvement in the welfare of rural households if attention is given solely to increasing (land) agricultural productivity. In fact a look at the success stories of agriculture-lead poverty reduction reveals that the successes were realized mainly through means (such as extensification, commercialization and/or crop diversification) other than increases in agricultural (land) productivity. For instance households that moved out of poverty in Kenya between 1997 and 2007 more than doubled their landholdings and cultivated 70% more land in 1997 than in 2007 (Muyanga et al., 2010). Kristjanson et al. (2010) reports that 23% of households that graduated out of poverty attributed their success to increased land cultivation; 49% attributed it to crop diversification; and in areas of low potential for crop production, 50% of the households attributed their success to diversification away from maize to crops of higher value. Cunguara (2008) reports that between 2002 and 2005, households that moved out of poverty in Mozambique increased land cultivated by 10%. In Zambia, households moving out of poverty increased their landholdings from 5ha to 23ha (Banda et al., 2011).

It is also worth mentioning that agricultural extensification is not likely to be realized in most parts of SSA because the average landholding and farm size is very small for most agricultural households (Harris and Orr, 2013). The current landholding in Malawi for instance is less than a hectare per household, and with increasing population pressure, landholdings are likely to get smaller in the future. Belieres et al. (2013) and Nagayets (2005) also report that about 80% of farms in SSA are less than 2ha. Hence crop diversification from crops of low value to high-value crops appears to be the channel that can complement growth in agricultural (land) productivity to bring about the needed improvement in the living standards of rural agricultural households in SSA.

2.7.2.2 Other Determinants of Household Welfare

Given the significant but small effect that increases in agricultural productivity has on the welfare of rural agricultural households, and the fact that agricultural extensification is not likely to be realized, the crop production ought to be supported by other policy moves. This study finds that other important determinants of the welfare of rural agricultural households include household size, landholdings, ownership of crop storage, and prices of consumable goods[8]. All these factors have the expected effect. A unit increase in household size will decrease the per capita consumption expenditure by 14.8%, increase the poverty gap and severity of poverty by 3.1 and 1.6 percentage points respectively; reduce caloric intake by 10.4; and increase the probability of being poor and food insecure by 8.4%. Given the average households size of about 5 (in the sample used

[8] The discussion of the effect of the other determinants of welfare is based on the estimates from the welfare models in which agricultural productivity is measured by maize yield i.e. tables 2.A1, 2.A2, 2.A5). The estimates from the models in which agricultural productivity is measured by value of crops per output are very similar.

for this analyses) and the fact that it increases significantly over time, there is the need for the promotion of smaller household size among rural agricultural households.

Landholding improves the welfare of households. A percentage increase in the hectares of land owned by households will increase per capita consumption expenditure by 0.129%, decrease the poverty gap by 0.047 and 0.024 percentage points respectively; increase caloric intake by 0.054%; and reduces probability of being poor and food insecure by 0.082%. The positive effect of landholding on welfare has important implications for poverty reduction because landholdings generally are small and are likely to get smaller with increasing population pressure.

Ownership of a crop storage structure improves the poverty status of households, but has no significant effect on food security. Ownership of storage structures increases per capita consumption of households by 10.9%, and reduces the poverty gap and severity of poverty by 3 and 1.5 percentage points respectively. The positive effect on poverty of ownership of crop storage structures is expected because storage structures enables farmers to keep part of their produce for sale during the lean season when crop prices are relatively higher than harvest season prices. Currently, only about 16% of rural agricultural households own crop storage structures. This implies that more than 80% of rural farmers are unable to take advantage of higher lean season prices, a situation that can potentially thwart pro-agriculture poverty reduction efforts.

A higher price of consumable goods exacerbates the poverty status of households. A percentage increase in prices of consumable goods (food and non-food) will, all things being equal, reduce per capita consumption expenditure by 0.7%; increase poverty gap and severity of poverty by 0.3 and 0.2 percentage points respectively.

## 2.8 Conclusion and Policy Recommendation

Poverty and food insecurity are still major developmental challenges in sub-Saharan Africa (SSA). Because poverty is disproportionally rural in SSA, and a majority of the rural poor depend either directly or indirectly on agriculture for livelihood, it is widely believed that agriculture is a major channel through which poverty can be reduced in the sub-region. This notion is perhaps also based on the historical evidence that agriculture played an integral role in the marked success achieved in poverty reduction in Asia, and the evidence that growth in agriculture tend to be more beneficial to the poor than growth in other sectors of developing economies. To date there has been numerous debates but little empirical evidence about the potential effect of improvements in agricultural productivity on the welfare of agricultural households in SSA.

With these considerations in mind the present study measures the extent to which agricultural productivity affects the welfare of agricultural households in Malawi using two waves of a nationally representative panel data from Malawi. Welfare was measured in terms of poverty and food insecurity, and agricultural productivity was measured by maize yield and value of crop per hectare. Depending on the measure of welfare the effect of agricultural productivity on each of the measures of welfare was estimated using household fixed effects, a two-part estimator or a correlated random effects ordered probit estimator. The study also shows that agricultural productivity is not necessarily endogenous in household welfare models.

The results indicate that increasing agricultural productivity has a statistically significant and positive effect on the welfare of rural agricultural households in Malawi. However, the impact is small in terms of economic magnitude. Hence, overall, this study suggest that agricultural productivity will have to increase by a large amount in order to bring about the needed improvement in the welfare of rural agricultural households. Thus, rural household welfare-improving initiatives must go beyond the confines of increasing agricultural (land) productivity. Other findings of this study suggest that non-agricultural measures such as the promotion of off-farm income-generating activities, smaller household size, and ownership of crop storage house and favorable prices of consumable goods should also be considered as possible welfare-improving initiatives.

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Table 2-1 Definition of Variables in the Welfare Model

| Variables | Definition |
|---|---|
| **Dependent Variables (measures of welfare)** | |
| ***Poverty measures*** | |
| Per capita consumption expenditure | Expenditure on food, non-food, durables goods and housing per capita ('000 MKW) |
| Relative deprivation in terms of consumption expenditure | Stark and Taylor's (1989) index ('000 MKW) |
| Poverty gap | Foster-Greer-Thorbecke (1984) index [0,1] |
| Severity of Poverty | Foster-Greer-Thorbecke (1984) index [0,1] |
| ***Food security measures*** | |
| Per capita caloric intake | Caloric intake from all sources of food (home-cooked and those purchased from outside) ('000) |
| Relative deprivation in terms of caloric intake | Stark and Taylor's (1989) index ('000 MKW) |
| ***Poverty and food security measure*** | |
| Composite welfare | 1 = Poor and food insecure; 2 = Non-poor but food insecure or poor but food secured; 3 = Non-poor and food secured |
| **Covariates** | |
| *Agricultural Productivity* | |
| Value of crops per hectare | Value of annual crops per hectare ('000 MKW per hectare) |
| Maize yield | Quantity of maize produced per hectare ('000 Kg/ha) |
| ***Other sources of income*** | |
| Number of livestock | Number of livestock owned by the household |
| Net income from tree/permanent crop production | Net income from tree/permanent crop production ('000 MKW) |
| Net income from non-farm enterprise | Net income from -farm enterprise ('000 MKW) |
| Agricultural wage | Total agricultural wage earned ('000 MKW) |
| Other sources of income | = 1 if household has other sources of income such as ag and non-ag wage, remittances etc. |
| ***Household characteristics*** | |
| Household size | Number of people in the household |
| Dependency ratio (%) | Percentage of dependents in the household |
| Male-headed | = 1 if household is headed by a male |
| Age of HH head | Age of household head (years) |
| Age of household head squared | Squared of the age of household head |
| Education of the most educated HH member | Number of years of education of the most educated household member |
| Landholding (Ha) | Hectares of land that household has the right to cultivate |
| Owns crop storage house | = 1 if household owns a crop storage house |
| Accessed credit | = 1 if household had access to credit of any sort |
| Extension for crop production | = 1 if household had access to extension service for crop production |
| ***Prices*** | |
| Commercial price of urea | Median price of urea in the enumeration (MKW/kg) |
| Laspeyres spatial price index | Laspeyres spatial price index (base = national price in March) |
| ***Household geo-variables*** | |
| Distance to nearest road | Distance from house to the nearest road (Km) |
| Distance to tobacco auction floor (Km) | Distance from house to nearest tobacco auction floor (Km) |
| Distance to boma (Km) | Distance from house to main district market (boma) in district in where household lives (Km) |
| Distance to weekly market (Km) | Distance from house to the nearest weekly market (Km) |
| Northern region | = 1 if household lives in the Northern region |
| Central region | = 1 if household lives in the Central region |
| Tropical-warm/subhumid | = 1 if household is located in the tropical-warm/subhumid agro-ecological zone |
| Tropical-cool/semiarid | = 1 if household is located in the tropical-cool/semiarid agro-ecological zone |
| Tropical-cool/subhumid | = 1 if household is located in the tropical-cool/subhumid agro-ecological zone |

Table 2-2 Descriptive Statistics

| Variables | Pooled | 2009/2010 agricultural year | | | 2012/2013 agricultural year | | |
|---|---|---|---|---|---|---|---|
| | Mean | Mean | Median | SD | Mean[b] | Median | SD |
| **Dependent Variables (measures of welfare)** | | | | | | | |
| ***Poverty measures*** | | | | | | | |
| Per capita consumption expenditure ('000) | 129.16 | 121.62 | 95.83 | 97.81 | 135.83*** | 108.92 | 93.57 |
| Relative deprivation in terms of consumption expenditure ('000) | 150.15 | 153.53 | 164.70 | 31.69 | 147.15*** | 157.64 | 35.33 |
| Poverty gap | 0.11 | 0.13 | | 0.20 | 0.09*** | | 0.17 |
| Severity of Poverty | 0.05 | 0.06 | | 0.11 | 0.04*** | | 0.09 |
| ***Food security measures*** | | | | | | | |
| Per capita caloric intake ('000) | 2.4 | 2.45 | 2.13 | 1.28 | 2.36 | 2.09 | 1.20 |
| Relative deprivation in terms of caloric intake ('000) | 1.86 | 1.77 | 1.96 | 0.69 | 1.95*** | 2.13 | 0.67 |
| ***Poverty and food security measure*** | | | | | | | |
| Composite Welfare | 2.03 | 2.00 | 2.00 | 0.85 | 2.06 | 2.00 | 0.84 |
| **Independent variables** | | | | | | | |
| ***Agricultural Productivity*** | | | | | | | |
| Value of crops per hectare ('000) | 48.26 | 44.44 | 27.77 | 46.86 | 51.65 *** | 35.45 | 60.27 |
| Maize yield ('000) | 1.51 | 1.34 | 1.01 | 1.14 | 1.65*** | 1.17 | 1.94 |
| ***Other sources of income*** | | | | | | | |
| Number of livestock | 0.30 | 0.28 | 0.05 | 0.84 | 0.33 | 0.05 | 1.02 |
| Net income from tree/permanent crop production ('000) | 2.31 | 1.49 | 0.00 | 4.00 | 3.03*** | 0.00 | 12.64 |
| Net income from off-farm enterprise ('000) | 22.32 | 11.17 | 0.00 | 50.97 | 32.20*** | 0.00 | 109.17 |
| Agricultural wage | 25.82 | 19.52 | 0.00 | 42.45 | 31.39*** | 0.00 | 64.74 |
| Other sources of income (%) | 32.5 | 27.6 | 0.00 | 45 | 36.80*** | 0.00 | 49 |
| ***Household characteristics*** | | | | | | | |
| Household size | 5.08 | 4.9 | 5.00 | 2.26 | 5.23*** | 5.00 | 2.21 |
| Dependency ratio (%) | 122.56 | 124.54 | 100.00 | 86.40 | 120.8 | 100.00 | 87.58 |
| Male-headed | 0.74 | 0.74 | 1.00 | 0.43 | 0.74 | 1.00 | 0.43 |
| Age of HH head | 43.49 | 43.77 | 40.00 | 16.48 | 43.24 | 40.00 | 15.41 |
| Education of the most educated HH member | 6.98 | 6.54 | 7.00 | 3.47 | 7.38*** | 8.00 | 3.10 |
| Quantity of land (Ha) | 0.78 | 0.74 | 0.61 | 0.60 | 0.82 | 0.57 | 6.03 |
| Owns crop storage house (%) | 16 | 18 | 0.00 | 0.40 | 13*** | 0.00 | 0.34 |
| Accessed credit (%) | 17 | 10 | 0.00 | 0.30 | 23*** | 0.00 | 0.41 |
| Extension for crop production (%) | 53 | 0.4 | 0.00 | 0.49 | 66*** | 1.00 | 0.48 |
| ***Prices*** | | | | | | | |
| Price of urea | 222.63 | 223.2 | 232.02 | 22.87 | 222.12 | 240.00 | 47.32 |
| Laspeyres spatial price index | 86.86 | 90.82 | 90.82 | 8.45 | 83.36*** | 82.06 | 7.26 |
| ***Household geo-variables*** | | | | | | | |
| Distance to nearest road | 9.81 | 9.47 | 5.33 | 9.65 | 10.11 | 6.00 | 9.95 |
| Distance to tobacco auction floor (Km) | 77.91 | 77.26 | 71.57 | 50.31 | 78.5 | 73.00 | 49.77 |
| Distance to boma (Km) | 38.21 | 47.7 | 46.42 | 26.94 | 29.81*** | 27.00 | 25.37 |
| Distance to weekly market (Km) | 4.38 | 4.57 | 4.00 | 5.71 | 4.21 | 3.00 | 6.37 |
| Northern region | 0.12 | 0.12 | 0.00 | 0.42 | 0.11 | 0.00 | 0.41 |
| Central region | 0.43 | 0.42 | 0.00 | 0.48 | 0.43 | 0.00 | 0.49 |
| Tropical-warm/subhumid | 0.27 | 0.27 | 0.00 | 0.45 | 0.28 | 0.00 | 0.45 |
| Tropical-cool/semiarid | 0.18 | 0.18 | 0.00 | 0.37 | 0.18 | 0.00 | 0.37 |
| Tropical-cool/subhumid | 0.03 | 0.03 | 0.00 | 0.24 | 0.02 | 0.00 | 0.23 |
| Graded/Graveled | 0.27 | 0.24 | 0.00 | 0.44 | 0.30*** | 0.00 | 0.44 |
| Dirt road (maintained) | 0.53 | 0.54 | 0.00 | 0.50 | 0.52 | 1.00 | 0.50 |
| Dirt track | 0.05 | 0.06 | 0.00 | 0.25 | 0.04 | 0.00 | 0.17 |

[b] Stars indicate significant difference in mean between 2009/2010 and 2012/2013 agricultural years; * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 2-3 Elasticity of Agricultural Productivity on Household Welfare

| Measure of Agricultural Productivity | Measure of household welfare | Estimates | Range of Estimates [based on Oster (2015)][a] |
|---|---|---|---|
| Log of maize yield | *Poverty measures* | | |
| | Log of per capita consumption expenditure | 0.132*** (0.020) | [0.132 0.173] |
| | Log of relative deprivation | -0.058*** (0.009) | [-0.058 -0.076] |
| | Poverty gap | -0.034*** (0.006) | -- |
| | Severity of poverty | -0.017*** (0.004) | -- |
| | *Food security measures* | | |
| | Log of calories consumed per capita | 0.060** (0.023) | [0.060 0.107] |
| | Log of relative deprivation | -0.036 (0.024) | [-0.036 -0.085] |
| | *Composite welfare*[b] | | |
| | Probability of being poor and food insecure | -0.057*** (0.017) | -- |
| | Probability of being non-poor and food secure | 0.060*** (0.018) | -- |
| Log of value of crop per ha | *Poverty measures* | | |
| | Log of per capita consumption expenditure | 0.096*** (0.017) | [0.096 0.130] |
| | Log of relative deprivation | -0.042*** (0.007) | -0.042 -0.058] |
| | Poverty gap | -0.019*** (0.004) | -- |
| | Severity of poverty | -0.008*** (0.002) | -- |
| | *Food security measures* | | |
| | Log of calories consumed per capita | 0.054*** (0.019) | [0.054 0.094] |
| | Log of relative deprivation | -0.040* (0.020) | -0.040 -0.081] |
| | *Composite welfare*[b] | | |
| | Probability of being poor and food insecure | -0.043*** (0.010) | -- |
| | Probability of being non-poor and food secure | 0.046*** (0.011) | -- |

[a]psacalc of Oster (2015) only applies to linear regression.
[b]The estimates of composite welfare presented in this table are the marginal effects of the probability of being in the first (poor and food insecure) and third (non-poor and food secure) categories. See tables 2.A5 and 2.A6 in appendix A for the estimates in the full model that has estimates of all the three categories
*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses

Table 2-4 Effect of Increases in Agricultural Productivity on the Transition of Households Out of Poverty

| Increase in Agricultural productivity | % of Poor households in 2013 | | % of Ultra Poor households in 2013 | | Number of people lifted out of poverty | | Number of people lifted out of ultra-poverty | |
|---|---|---|---|---|---|---|---|---|
| | Maize yield | Value of crop | Maize yield | Value of crop | Maize yield | Value of crop | Maize yield | Value of crop |
| 0% | 40.78 | 40.78 | 11.00 | 11.00 | -- | -- | -- | -- |
| 5% | 35.74 | 35.19 | 9.39 | 8.61 | 555,969.31 | 573,745.06 | 253,024.14 | 295,786.78 |
| 10% | 35.45 | 35.19 | 9.26 | 8.39 | 555,969.31 | 573,745.06 | 260,351.78 | 295,786.78 |
| 15% | 35.45 | 34.99 | 9.26 | 8.39 | 555,969.31 | 585,601.25 | 260,351.78 | 295,786.78 |
| 20% | 35.19 | 34.99 | 9.11 | 8.39 | 567,825.50 | 585,601.25 | 260,351.78 | 295,786.78 |
| 25% | 35.08 | 34.70 | 9.11 | 8.39 | 571,433.63 | 598,899.56 | 260,351.78 | 295,786.78 |
| 30% | 34.99 | 34.67 | 9.11 | 8.27 | 576,370.13 | 598,899.56 | 260,351.78 | 302,815.31 |
| 35% | 34.77 | 34.67 | 9.05 | 8.10 | 581,876.44 | 598,899.56 | 260,351.78 | 302,815.31 |
| 40% | 34.62 | 34.67 | 8.65 | 8.10 | 588,786.94 | 598,899.56 | 270,491.66 | 302,815.31 |
| 45% | 34.36 | 34.47 | 8.65 | 8.10 | 601,266.94 | 603,817.88 | 270,491.66 | 302,815.31 |
| 50% | 34.01 | 34.38 | 8.46 | 7.97 | 622,015.25 | 603,817.88 | 281,718.41 | 310,142.97 |
| 55% | 33.95 | 34.27 | 8.34 | 7.97 | 622,015.25 | 610,175.81 | 288,746.94 | 310,142.97 |
| 60% | 33.86 | 34.16 | 8.00 | 7.94 | 626,781.38 | 616,297.88 | 308,266.31 | 311,868.25 |
| 65% | 33.76 | 34.16 | 7.94 | 7.94 | 626,781.38 | 616,297.88 | 311,868.69 | 311,868.25 |
| 70% | 33.76 | 34.16 | 7.79 | 7.81 | 626,781.38 | 616,297.88 | 320,494.97 | 311,868.25 |
| 75% | 33.62 | 34.11 | 7.79 | 7.81 | 631,964.19 | 619,649.56 | 320,494.97 | 311,868.25 |
| 80% | 33.17 | 34.11 | 7.64 | 7.81 | 657,617.88 | 619,649.56 | 320,494.97 | 311,868.25 |
| 85% | 33.17 | 34.06 | 7.64 | 7.81 | 657,617.88 | 622,357.19 | 320,494.97 | 311,868.25 |
| 90% | 33.08 | 34.01 | 7.64 | 7.81 | 662,993.94 | 625,088.63 | 320,494.97 | 311,868.25 |
| 95% | 33.08 | 34.01 | 7.64 | 7.81 | 662,993.94 | 625,088.63 | 320,494.97 | 311,868.25 |
| 100% | 33.03 | 34.01 | 7.56 | 7.81 | 662,993.94 | 625,088.63 | 325,017.94 | 311,868.25 |
| ***Raising productivity of all households to:*** | | | | | | | | |
| Quarter of district highest | 32.16 | 31.17 | 6.60 | 6.52 | 728,040.63 | 763,563.25 | 327,458.78 | 374,495.47 |
| Half of district highest | 28.98 | 28.44 | 5.95 | 5.13 | 863,750.31 | 890,375.00 | 350,718.66 | 420,365.44 |
| Three-quarters of district highest | 27.29 | 27.34 | 5.23 | 4.76 | 909,683.69 | 934,795.81 | 377,188.38 | 424,577.97 |
| District highest (full potential?) | 25.32 | 26.69 | 5.14 | 4.76 | 1,021,293.50 | 966,361.06 | 382,145.03 | 424,577.97 |

# CHAPTER 3: FERTILIZER PROFITABILITY IN MALAWI

## 3.1 Introduction

Improving agricultural productivity is widely regarded as a channel for reducing poverty and food insecurity in sub-Saharan Africa (SSA). This view is based on the heavy reliance of poor and food insecure households on agriculture. Unfortunately, agricultural productivity has been very low in SSA: since the 1960s, average per capita annual growth in agricultural productivity has been less than 1% for the continent as a whole, and – at times – negative for some sub-regions (FAO statistics, 2013). Lagging agricultural growth in SSA has mainly been explained by low fertilizer use (Morris et al., 2007). Africa has one of the lowest fertilizer application rates among the developing regions of the world. Morris et al (2007) observed that when countries and crops in similar agro-ecological zones are compared, the rate of fertilizer application is much lower in Africa than in other developing regions. Fertilizer use is particularly important in Africa because the continent's soils are inherently poor in nutrients, and over the past decades, land-use practices have further worsened soil fertility through leaching, nutrient mining by crops and inadequate erosion control (Henao and Baanante, 2006).

The low use of fertilizer in SSA could be attributed to both demand-side and supply-side factors. The first and most obvious demand-side factor that could potentially explain the low use of fertilizer in Africa relates to profitability. Farmers' demand for commercial fertilizer is weak because fertilizer use is probably unprofitable or only marginally profitable to most farmers. Incentives to use fertilizer are often undermined by the low fertilizer response rate, high variability of crop yields, high fertilizer prices relative to crop output prices, and limited access to credit. The demand for fertilizer is further exacerbated by lack of information about the availability and cost of fertilizer, the inability of farmers to raise resources needed to purchase fertilizer, and lack of knowledge on the part of many farmers about how to use fertilizer efficiently. On the supply side, the factors that potentially undermine the use of commercial fertilizer by farmers include unfavorable business climate, excessive regulations, an abundance of taxes and fees, and high levels of rent seeking.

With these considerations in mind, the objective of the present study is to use nationally representative household level data from Malawi to analyze the profitability of fertilizer use in maize production. Specifically, the study seeks to answer the following questions: 1) what is the level of nitrogen use efficiency (NUE)[9] and how does it vary across the districts of Malawi? 2) to what extent is the use of fertilizer in crop production profitable in Malawi? 3) how does Malawi's fertilizer subsidy affect the profitability of fertilizer use?

[9] NUE is defined as the kilograms of maize obtained from an additional kilogram of nitrogen applied.

The study focuses on Malawi for two reason. First, productivity growth in Malawi's agriculture is typical of countries in SSA. For the past two decades, the productivity of most agricultural crops in the country has increased only modestly. Even now, the already modest increase in productivity is further undermined by population growth (MoAFS, 2010). The Ministry of Agriculture and Food Security (2010) estimates that the country's yield gap – the difference between potential yield and the actual yield of the average farmer (1,536 kg/ha for maize in 2013) – ranges from 38-53% for cereals, and 40-75% for legumes (Lobell et al., 2009). This implies substantial room for productivity improvements. Yield improvements likely will be essential for reducing poverty and improving food security in Malawi because there is limited room for area expansion among smallholders (Dorward 2006; Ricker-Gilbert et al. 2014). Secondly, since the government of Malawi (GoM) has been implementing a large-scale Farm Input Subsidy Program (FISP) from the 2005/2006 agricultural season, focusing on Malawi provides an opportunity to analyze how fertilizer profitability can inform the geographical targeting of large-scale farm input subsidy programs, and how the subsidy program affects the profitability of fertilizer use. In terms of scope and coverage, FISP is perhaps the most well-known farm input subsidy program in Africa. Through FISP, GoM currently provides approximately 50% of the country's agricultural household with coupons that allow for inorganic fertilizer and improved maize seed purchases at up to a 95% discount.

The study adds to literature by extending the work of Xu et al. (2009) and Sheahan et al. (2012). Xu et al. (2009) and Sheahan et al. (2012) used nationally representative panel data from Zambia and Kenya respectively, and the Mundlak-Chamberlain model, to analyze the profitability of fertilizer use in maize production. These studies are extended in three ways in the present study. First, by virtue of the availability of a variable that identifies gardens over time in the two-wave nationally representative panel data used in the analyses, this study is able to control for plot-level unobserved heterogeneity[10]. Controlling for such plot-level unobserved heterogeneity helps improve upon the validity of the estimates. Second, this study accounts for all the maize prices – farm gate price, lean season market price and import parity price – that farmers can potentially face. While most farmers sell their produce at the farm gate, others sell at nearby market centers and depending on the month in which sales are made, face either the harvest season (May to October) price or the lean season price (November to April). Apart from representing a price that farmers can potentially face in the maize market, the lean season maize price also represents the opportunity cost to farmers of purchasing maize if they are not able to produce enough maize for to avoid household-level, seasonal maize deficits. The import parity price of maize is also considered in order to account for the government's opportunity cost to home production of having to import maize. Accounting for all of these output prices will help to provide a broader picture of the profitability of fertilizer use. Third, the present study extends the scope of previous work on fertilizer profitability by using the NUE and profitability estimates to provide guidance for the geographical allocation of fertilizer subsidies and to shed more light on the question of whether farmers would be better-off with subsidized fertilizer or the cash equivalent of subsidized fertilizer.

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[10] A garden is defined as a continuous piece of land that is not split by river or a path wide enough to fit an ox-cart or vehicle, and can contain multiple plots.

The results indicate that, assuming positive transaction costs in the use of inorganic fertilizer, fertilizer use is on average not profitable in Malawi at commercial prices of fertilizer when maize is valued at either the farm gate price or lean season market price. The garden level analyses show that fertilizer use is profitable on only less than 1% of gardens when maize is valued at the farm gate price; and profitable on only 17.61% when maize is valued at the lean season market price. At prevailing market conditions, in order for the use of fertilizer to be profitable, the current nitrogen use efficiency estimated to be 11.89kg will have to increase by at least 137.17% when maize is valued at the farm gate price and by at least 41.34% when maize is valued at the lean season market price. It was also found that, at all rates of fertilizer subsidy, unless farmers are able to store their maize output and sell during the lean season, on average, farmers will be MKW 66.16 per kg of subsidized nitrogen better off with the cash equivalent of the subsidy than participating in the subsidy program if maize is valued at the farm gate price. Finally, the study finds that the government recommended rate of fertilizer application is 116% to 119% more profitable than the rate at which farmers are currently applying fertilizer.

## 3.2 Conceptual Framework

The goal of this study is to assess the profitability of inorganic fertilizer use in Malawi. In doing so, the yield function and the profitability of fertilizer use are derived from the farm profit component of the agricultural household model of Sing, Squire and Strauss (1986). Farmers are considered to be firms whose production set is made up of food and cash crops. Maize is the most widely cultivated crop in Malawi – it is cultivated by about 90% of farmers on 70% of their farm plots – and the most important crop in terms of fertilizer application (NSO, 2013). The study therefore focuses on farmers' decision to produce maize using inorganic fertilizer and other inputs, with the objective of maximizing farm profit, $\pi$, which is given by:

$$\pi = P_Y Y(I) - P_I I \tag{3.1}$$

where $Y$ and $P_Y$ are quantity and price of maize respectively; $I$ is a vector of inputs used in the production of maize; and $P_I$ is a vector of the prices of the inputs used in the production of maize. The term *Y(I)* represents the agronomic production function where a vector of inputs $I$, are turned into maize output $Y$. In the literature, $I$ typically includes growth inputs such as nutrients, seed and water; and facilitating inputs such as labor and pesticides (Frank et al. 1990; Guan et al, 2006)[11]. Previous literature extends the facilitating inputs to include household characteristics such as wealth, education, household size and dependency ratio (Xu et al, 2009; Sheahan et al. 2012). The present study categorizes the growth and facilitating inputs into plot-level and household-level variables. The plot-level variables include such variables as nutrient and seed application rates that vary across plots; and the household-level variables include household characteristics such as wealth and education that vary across households but the same across plots managed by the same household. The full list of variables is presented in Table 3.1.

In the present study, the production function of $Y$ in equation (3.1) is given by:

$$Y = f(N, X, H, W) \tag{3.2}$$

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[11] Growth inputs those inputs that are directly involved in the biological process of plant growth and development. The facilitating inputs are not directly involved in the growth and development process of plants but influence the response rate of plants to the growth inputs (Guan et al, 2006).

where $Y$ is maize yield in kilograms of maize per hectare, $N$ is the rate of nitrogen (from inorganic fertilizer) application, $X$ is a vector of other plot-level agronomic inputs including the quantity of seeds sown, the amount of labor used on the plot, whether or not the plot is planted to a hybrid maize variety etc. $H$ is a vector of household-level variables such as asset ownership, quantity of arable land owned by the household, educational status of the household, adult-equivalent household size, dependency ratio etc. that are likely to affect maize production. $W$ is a vector of weather variables including rainfall and temperature.

Taking the first order condition of profit maximization with respect to the nutrient variable and rearranging terms results in equation (3.3) below[12]:

$$P_Y * MP_N = \ P_N \tag{3.3}$$

where $MP_N$ is the marginal product of nitrogen; and $P_Y$ and $P_N$ represent the prices of maize and nitrogen respectively. Accordingly, the left-hand side of equation (3.3) is the marginal revenue product of inorganic fertilizer application, measuring the rate at which revenue from maize production increases with the amount used of nitrogen. A household's decision to use inorganic fertilizer in the production of maize is influenced by the extent to which the input is profitable – the higher the profitability of fertilizer use, the higher the incentive for farmers to use the input. From equation (3.3), the extent of fertilizer profitability to a household is given by $(P_Y * MP_N \ - \ P_F)$, thus profitability of fertilizer use depends on the household's yield response rate to fertilizer, the price of

[12] The first order condition of the profit function is taken with respect to only the inorganic fertilizer variable because inorganic fertilizer is the variables of interest.

maize and the price of fertilizer. $MP_N$, the only unknown in equation (3.3), is obtained from the estimation of equation (3.2).

## 3.3 Empirical Model and Estimation Strategy

In order to study the profitability of fertilizer use by farmers in Malawi, the conceptual yield function in equation (3.2) is specified using fixed effects (district, enumeration area, household and garden) and multilevel models. These specifications will together provide a good evaluation of the robustness of the estimates to model specifications. The fixed effects model is specified generally as:

$$Y_{ijt} = \beta_1 N_{ijt} + X_{ijt}\beta_x + H_{ijt}\beta_h + W_{ijt}\beta_w + \varepsilon_{ijt} \qquad (3.4a)$$

$$\varepsilon_{ijt} = c_i + \varepsilon_{ijt} \qquad (3.4b)$$

where $i$ and $t$ represent plot and time respectively; $j$ is the indicator for fixed effects (district, enumeration area, household or garden); $\varepsilon_{ijt}$ is a composite error term made up of time-invariant ($c_i$) and time-varying ($\varepsilon_{ijt}$) unobserved factors; $\beta_1$ is the nitrogen use efficiency (NUE), defined as the kilograms of maize obtained from the application of a kilogram of nitrogen; and $\beta_x, \beta_h$ $and$ $\beta_w$ are the parameters for other plot-level variables, household variables and weather variables respectively. The rest of the variables are as defined above.

Yield is measured as maize-equivalent output per hectare of land. Maize-equivalent output is used instead of maize output because, as in other developing countries, maize is usually intercropped in Malawi. Total output from any particular plot is converted to maize equivalent output (*ME*) using an output index given by equation (3.5) (Liu and Myers, 2009; Sheehan et al., 2013):

$$ME_p = Z_{maize,p} + \frac{\sum_s Z_{sp} P_s}{P_m} \tag{3.5}$$

where $Z_{maize,p}$ is kilograms of maize harvested from plot $p$; $Z_{sp}$ is kilograms harvested of crop *s* intercropped with maize on plot *p*; and $P_s$ and $P_m$ are the market price of crop $s$ and maize respectively. Equation (3.5) reduces to $Z_{maize,p}$ on pure-stand maize plots.

The multilevel specifications are considered in addition to the fixed effects specifications because they allow for the estimation of households-specific and garden-specific NUEs. The estimation of NUE at such disaggregated levels is of particular interest in this study because it allows the study to analyze the variation in NUE, and subsequently the profitability of fertilizer use, at the lowest disaggregated level possible. The use of multilevel models has two additional advantages. First, the data for the analysis has a hierarchical structure: plots are nested within gardens which are in turn nested within households (farm households in Malawi and other parts of developing countries usually cultivate crops on multiple plots). The existence of such a hierarchy in the data has implications for statistical validity and should therefore not be ignored (Goldstein, 1995; Elhorst, 2014; Carrado and Fingleton, 2011). The multilevel model accounts for the hierarchical structure between plots, gardens and households by modelling variations at all levels. Moreover, yield from plots belonging to the same garden and household are likely to be correlated because they share the same management and related conditions. The multilevel specification corrects for these intra-garden and intra-household correlations[13]. Second, the multilevel model distinguishes (explicitly) between plot-level and household-level covariates in the model by allowing for the coefficients of the plot-level variables to vary within gardens and households. This is particularly important in this study because of the interest in observing the geographical variation of NUE.

For yield on plot $p$, belonging to household $h$, the model at the various level of the hierarchy is specified as:

Plot-level model

$$Y_{ph} = \beta_{0h} + \beta_{1h}N_{ph} + X_{ph}\beta_x + \varepsilon_{ph} \qquad (3.6)$$

where $Y_{ph}$ is yield; $N_{ph}$ is nitrogen application rate; $X_{ph}$ is a vector of other plot-level variables affecting maize yield; and $\varepsilon_{ph}$ represents the plot-level error term. $\beta_{0h}$ is the random intercept, varying across households, but has the same value for individual plots belonging to household $h$. $\beta_{0h}$ therefore measures the mean yield for plots in household $h$. $\beta_{1h}$ is the random slope for the nitrogen variable which varies across households. $\beta_x$ is a vector of fixed coefficients for the other plot-level variables, where the subscript $x$ represents the corresponding plot-level variable in vector $X_{ph}$. Unlike NUE ($\beta_{1h}$), these coefficients are fixed because their variation across households is not of any particular interest in this study. Moreover, fixing these coefficients will reduce the complexity of the full model specified below.

Household-level model

[13] The use of single-level models (which assume that yields are independent across plots) in the presence of intra-household in yield will lead to spuriously small standard errors, which will in turn result in too short confidence intervals and too small p-values.

The study hypothesizes that variability in the random intercept ($\beta_{0h}$) is explained by household level variables. Thus, in the household-level model, equations (3.7a) and (2.7b), the random intercept is expressed as a function of household-level variables.

$$\beta_{0h} = \beta_{00} + H_h \alpha_{0m0} + U_{0h} \tag{3.7a}$$

$$\beta_{1h} = \beta_{10} + U_{1h} \tag{3.7b}$$

where $H_h$ is a vector of household-level variables . $\beta_{00}$ and $\beta_{10}$ are the household-level group effect for the intercept and the NUE (i.e. the mean yield and NUE ) respectively; and household-specific variation around these values are represented by $U_{0h}$ and $U_{1h}$. $\alpha_{0m0}$ represents the contribution of household variables to the variation in the random intercept, where the subscript *m* represents the corresponding household-level variable in vector $H_h$.

Full model

Substitution of equations (3.7a) and (3.7b) into equation (3.6) results in the full multilevel model which is given by:

$$Y_{phct} = \beta_{00} + \beta_{10} N_{ph} + X_{ph}\beta_k + H_h \alpha_{0m0} + \left(U_{0h} + U_{1hct} N_{ph} + \varepsilon_{ph}\right) \tag{3.8}$$

The terms in bracket, $\left(U_{0h} + U_{1hct} N_{ph} + \varepsilon_{ph}\right)$, represent the total error term in the full model — $\varepsilon_{ph}$ from the plot level, and $U_{0h}$ *and* $U_{1h}N_{ph}$ from the household level.

### 3.3.1 Potential Endogeneity of Fertilizer Use in Crop Yield Function

The nitrogen variable in the yield function is potentially endogenous, in that the decision to apply, and the rate of application of, nitrogen on a particular plot is likely to be correlated with unobserved farmer characteristics such as managerial skills or ability, and unobserved plot specific characteristics such as variation in soil quality characteristics, that are likely to affect crop yield. For instance farmers may be more likely to apply more nitrogen to plots of good soil quality in order to maximize the returns to the input. Failure to account for such correlation between the nitrogen variable and the unobserved household and plot-level characteristics would render the estimates of NUE inconsistent.

The unobserved variables could be time invariant factors such as farmers' managerial skills or time variant factors such as soil characteristics. The study addresses the bias resulting from unobserved time-invariant farmer and plot-level variables using garden-level fixed effects. To the best of my knowledge, this study is the first to control for unobserved time-invariant factors using garden-level fixed effects. The garden-level fixed effects model attenuates the potential bias by using the variation in nitrogen application within a garden over time to identify the causal effect of the rate of nitrogen application on yields (Wooldridge, 2010). Fixed effects does not however deal with unobserved time-varying factors, so even after controlling for unobserved heterogeneity with fixed effects, the estimate of the effect of the rate of nitrogen application on yield will still be inconsistent if $N_{ijt}$ is correlated with $\varepsilon_{ijt}$, unobserved time-varying factors.

The study accounts for the potential correlation between the nitrogen variable and the unobserved time-varying factors by taking advantage of the availability of variables on soil characteristics to control for plot-level factors such as slope, extent of erosion, type of soil, whether or not the plot is swampy, and the overall (subjective) soil quality of the plot. After controlling for such important but seldom available plot-level variables, the remaining unobserved time varying factors will pose no significant bias to the validity of the NUE estimates.

Another factor that could potentially threaten the validity of the NUE estimates is measurement error in the maize yield and nitrogen application rate variables. However, because the maize yield and nitrogen application rate variables were computed with GPS measured plot sizes instead of farmers' estimations, the study is confident that these variables were measured with little or no errors.

## 3.4 Fertilizer Profitability

Fertilizer profitability is measured with Marginal Value Cost Ratio (MVCR) which represents the extent by which farm income will increase if the rate of nitrogen application increases. MVCR is expressed as:

$$MVCR = \frac{NUE * P_{maize}}{P_N} \tag{3.9}$$

where $NUE$ is the nitrogen use efficiency; and $P_{maize}$ and $P_N$ are the prices of maize and nutrients respectively. Three prices of maize are considered in the profitability analyses – the farm gate price, the lean season market price and the import parity price. All three of these prices are considered in order to account for all the potential maize prices that farmers are likely to face. Harvest season maize price is not considered because it is very similar in magnitude to the farm gate maize price. The similarity in magnitude between the harvest season market price of maize and the farm gate price is most likely due to the fact that most farmers sell their produces in the harvest season. The price of nitrogen, $P_N$, is computed using the prices and nitrogen composition of *chitowe* (NPK

23:21:0 +4S) and the urea fertilizer, the two main fertilizers used in maize production. Following Xu et al. (2009), let $f$ be the amount of each of chitowe and urea required for a kilogram of nitrogen. Given the 1:1 application ratio of chitowe and urea and their nitrogen components (23% for chitowe and 46% for urea), we have the following expression: $23\%f + 46\%f = 1$; and solving for $f$ results in $f = 1.449kg$. This means that a kilogram of nitrogen costs approximately 1.449 kilograms of each of *chitowe* and urea; hence [$P_N = 1.449 * (price\ of\ chitowe + price\ of\ urea)$].

Whether or not fertilizer is likely to be profitable depends on outcomes that are uncertain when fertilizer decisions are made, as well as costs associated with the use of fertilizer that are unknown to the analyst. If these uncertainties and unobserved costs are assumed to be zero, fertilizer use is deemed profitable if MVCR is at least one, an indication that an increase in the rate of fertilizer application will increase income from maize production. In the face of these uncertainties and unobserved costs however, an MVCR of at least two (meaning a risk premium of one) has been recommended in the literature to be required in order for fertilizer to be profitable (Xu et al., 2009; Sauer and Tchale, 2009; Bationo et al., 1992; FAO, 1985). The later rule of thumb is adopted in this paper so as to account for the uncertainties and many unobserved costs (henceforth transaction cost) associated with fertilizer use in Malawi.

### 3.5 Data and Sample Selection

The data used in the analyses are a two-wave, nationally representative panel dataset collected by the national Statistical Office of Malawi (NSO) with support from the World Bank Living Standards Measurement Study – Integrated Surveys on

Agriculture (LSMS-ISA) program. The survey for the first wave of the dataset (Malawi's Integrated Household Survey – IHS3) was conducted from March 2010 through March 2011, and covered 12,271 households in 768 enumeration areas (i.e. 16 households from each EA). A sub-sample of the households considered in IHS3 were re-surveyed in 2013 to create the second wave of the dataset (Integrated Household Panel Survey -IHPS). IHPS tracked and re-interviewed 4000 households (3,247 original households, and 753 split-off households) from 204 of the 768 enumeration areas. An overwhelming majority, 76.80%, of the 3104 baseline households did not split over time; 18.49% split into two households; and remainder (4.70%) split into 3-6 households. Considering the 20 baseline household that died in their entirety between 2010 and 2013 and the fact that 4,000 households could be traced back to 3,104 baseline households, the dataset has an overall attrition rate of only 3.78% at the household level.

Each wave of the dataset is nationally representative. Apart from the island district of Likoma, the surveys covered the three regions of the country - North, Center and South. The three regions were segregated into urban and rural strata, with the urban strata consisting of Lilongwe City, Blantyre City, Mzuzu city and the Zomba municipality (NSO, 2005, 2012).

The households that were not resampled in IHPS were dropped from the dataset used in the analyses. Households from the urban enumeration areas were also dropped because farming in Malawi is predominantly rural. Among the rural households, the study focused on farm plots on which maize is the main crop. In the end, the sample size for the analyses consisted of 4688 households (2175 from IHS3 and 2513 from IHPS) and 6619 maize plots (3070 from IHS3 and 3549 from IHPS).

Attrition bias in the data could not be tested for because there are no regression-based tests for attrition when fixed effects or MC devise models are used with a panel of only two waves. A panel of more than two-waves are required for such tests (Wooldridge, 2010; Mason and Smale, 2013). That notwithstanding, the study is confident that attrition bias is not likely to be a concern because as indicated earlier, the attrition rate is only 3.78% at the household level.

## 3.6 Results

### 3.6.1 Descriptive Statistics

The descriptive statistics of the variables in the yield function are presented in table 3.2. The average maize yield in the 2009/2010 agricultural year was 1,240.61kg/ha and increased significantly to 1536.27kg/ha (24% increase) in the 2012/2013 agricultural year. The average yield estimates are higher than those reported for Nigeria over the same period of time (1154 kg/ha in 2010 and 1282 kg/ha in 2012), but lower than the average reported for Kenya (2707 kg/ha over 1997, 2000, 2004, 2007 and 2010) and Zambia (1779 kg/ha in 2009) (Liverpool-Tasie et al. 2015; Sheahan et al. 2012; Xu et al. 2009).

One would expect the increase in yield between survey waves to have resulted from an increase in the use of improved inputs such as inorganic fertilizer and hybrid seed, but the use of these inputs in the sample actually decreased significantly between the two agricultural seasons: the rate of nitrogen application decreased by about 13% (from 49.18 to 43.37 kg/ha), and the percentage of plots planted to hybrid maize varieties decreased by 4 percentage point (from 43.0% to 38.6%). Over the same period, labor utilization rate, seed application rate, the number of plots on which organic fertilizer was applied, and the number of plots on which the right type of basal fertilizer was applied increased significantly; and the average plot size and the number of plots managed by females decreased significantly. The combined yield-increasing effect of the significant changes in these variables probably outweighed the yield-decreasing effect of the decrease in the use of inorganic fertilizer and hybrid seed. The increase in yield could also have been partly due to farmers becoming relatively more efficient in the use of farm inputs in crop production.

Soil erosion appears to be a concern in maize production in Malawi. Nearly 40% of the maize plot operators report that their plots show signs of erosion. This could be related to the fact that about the same proportion of plots are not flat. Depending on the extent, soil erosion can potentially have a yield-decreasing effect by washing away the top soil and eventually depleting the soil of major nutrients. The high proportion of erosion-affected plots notwithstanding, only about 15% of the plots are reported by farmers to be of poor soil quality (about 45% of the plots are reported to be of good soil quality and the rest are reported to be of fair quality).

### 3.6.2 Production Function Results

Results of the maize production function are presented in table 3.3. The results are presented for seven model specifications: pooled OLS, district fixed effects, enumeration area fixed effects, household fixed effects, garden fixed effects, two-level multilevel model where plot and household are the first and second levels respectively, and a two-level multilevel model where plot and garden are the first and second levels respectively. The different specifications provide a good way to evaluate of the robustness of the estimates. The coefficient on nitrogen, the variable of interest, does not vary much across models, implying that the NUE estimate is robust to model specifications.

Depending on the estimator used table 3.3 shows that, the NUE estimates range from 9.24kg to 12.09kg, corroborating the widely held notion that the use of inorganic fertilizer is important for improvement in agricultural productivity. A detailed analysis of the NUE is provided in section 4.3 below. The NUE of the pooled OLS estimator (12.09kg) is the highest. This is expected because the pooled OLS estimator does not account for unobserved characteristics at any level (district, enumeration area, household or garden level). The estimates also show that the NUE of the garden fixed effects model (11.21kg) is higher than that of the household fixed effects model (9.24 kg); with the probable explanation being that unobserved plot level factors like soil quality put downward bias on the nitrogen coefficient that are controlled for in the garden fixed effects model but not in the household fixed effects model.

Yield on plots on which the rate of nitrogen application was above the recommended rate is about 332.63 kg/ha lower than it is on plots on which the recommended rate was followed. It is usually recommended that basal fertilizer application in maize production be done within a week after planting in order to ensure higher yields. The results indicate that compliance with this recommendation increases yield by about 169.24kg/ha, all thing being equal. The results further indicate that the use of organic fertilizer increases agricultural productivity by about 126.46 kg/ha.

There is a significant, inverse relationship between plot size and maize yield. All things being equal, a hectare increase in plot size will decrease yield by 847.80 kg/ha. Larger farms are usually not farmed as intensively as smaller farms and therefore are underutilized, resulting in lower productivity. This inverse relationship between plot-size and productivity is common in the literature (Carletto et al. 2013).

Labor utilization has a positive and significant effect on agricultural productivity. All things being equal, a day increase in total labor (sum of family, hired and exchange labor) increases maize yield by 0.95 kg/ha. The positive effect is expected because labor (family or hired) is needed for cultural practices such as land preparation, weeding, mulching, fertilizer application and pest control without which yield would be very low.

Soil quality has a positive and significant yield-increasing effect. The estimates show that, on average, yield on plots of good and fair quality is about 259.84kg/ha and 179.14kg/ha respectively higher than yield on plots of poor soil quality.

The gender and years of education of the plot manager are also significantly correlated with maize yield. Yield on female-managed plots is 113.27kg/ha lower than it is on male-managed plots. In a similar study in which agricultural productivity was measured by value of output per hectare, Kilic et al. (2015) observed that productivity on female-managed plots is 25% lower than on male-managed plots. The authors find that 82% of the gender differential in agricultural productivity is attributable to differences in endowments. It has been shown that closing this gender gap in agricultural productivity can potentially reduce the poverty rate by 2.2% and accordingly lift 23800 people out of poverty each year in Malawi (World Bank, 2015). The production function of this study also show that a year increase in the education of plot managers will all things being equal increase yield by 10.535 kg/ha.

Maize yield is also positively affected by ownership of agricultural tools and durable assets.  A unit increase in the index of agricultural tools and durable assets will all things being equal increase yield by 68.96kg/ha and 93.73kg/ha respectively. The positive relationship between asset ownership and maize yield is expected because farmers with more equipment are more likely to purchase and use fertilizer and other modern inputs in production.

Rainfall has a positive and significant effect on maize yield. A millimeter increase in total annual rainfall increases maize yield by 1kg/ha, all things being equal. This finding suggests that increasing farmers' access to irrigation facilities in low rainfall years could help boost agricultural productivity.

### 3.6.3 Distribution of Nitrogen Use Efficiency (NUE)

Generating the NUE at the most disaggregated level possible is of particular interest in this study. The use of a two-level multilevel model allows for the estimation of NUE at the garden level. Moreover, as table 3.3 indicates, the estimated NUEs of the garden-level multilevel model is very similar in magnitude to that of the garden-level fixed effects model, hence the study is confident that the estimated NUEs of the multilevel model is not biased. Using the garden-level multilevel model, the NUE is estimated to range from 2.82kg to 25.98kg with a mean and standard deviation of 11.82kg and 2.42 respectively (figure 3.1). Figure 3.1 also shows that NUE ranges between 10kg and 15kg for majority of the gardens (75%); between 5kg and 10kg for 16% of the gardens; between 15kg and 20kg for about 8% of the gardens; and at least 20kg for only about 1% of the gardens.

On average, the NUE estimated in this study is quite low, but consistent with past studies in Malawi. NUE in Malawi has been estimated to range from 7.1 kg to 11.0 kg by

Snapp et al (2013), between 6.6kg and 11.5 kg by Ricker-Gilbert and Jayne (2011, 2012); 11.3kg by Holden and Lunduka (2011); and 17 kg on experimental plots by Harou et al. (2015). The low NUE in Malawi is likely to be one of the main reasons why the use of commercial fertilizer for crop production is very low in the country. The fertilizer use literature suggests that the low NUE observed in this and other studies in Malawi is not an isolated case in SSA. The NUE has been estimated to be between 8kg and 13kg in Nigeria, and between 11kg and 20kg in Kenya (Liverpool-Tasie et al. 2015; Matsumoto and Yamano, 2011; Marenya and Barrett 2009; Sheahan et al, 2012). In terms of fertilizer (not just nitrogen application), the response rate has also been very low in some parts of SSA as well – 0.2kg to 2kg in Nigeria (Onuk et al., 2010; Gani and Omonona, 2009) and 0.12kg in the Mfantseman municipality of the Central Region of Ghana.

The study also estimates the mean NUE for each district and uses these estimates to categorize the districts into five groups. Such categorization will be useful in guiding the geographical targeting of the farm input subsidy program that the government is currently implementing. This is because coupons to be redeemed for subsidized inputs by beneficiaries are distributed through a decentralized process that begins with the headquarters of the Ministry of Agriculture and Food Security (MoAFS) allocating the coupons to districts. The NUE ranges from 12.19kg to 13.14kg for the first group of districts, 11.62kg to 12.18kg for the second group, 11.05kg to 11.61kg for the third group, 9.98kg to 11.04kg for the fourth group, and 9.58kg to 9.97kg for the fifth group (figure 3.4a). The first group of districts consists of Dowa, Ntchisi, Salima and Chiradzulu; the second group of consists of Mchinji, Kasungu, Nkhota kota, Karonga, Chitipa, Dedza, Ntcheu, Mangochi, Blantyre and Zomba; the third group consists of Nkhata Bay, Lilongwe and Balaka; the fourth group consists of Rumphi, Mzimba, Machinga, Neno, Mwanza, Phalombe, Mulanje and Thyolo; and fifth group consists of Chikwawa and Nsanje. Overall, the mean NUE for the districts in the central region are relatively higher than those in the northern and southern regions in that order. The study also finds a strong, positive correlation (0.87) between the spatial distribution of NUE and the spatial distribution of maize yield, implying that districts with the highest mean NUE have the highest mean yield (figures 3.4a and 3.4b)[14]. This categorization can serve as the basis for the geographical targeting for the farm input subsidy program that the government is currently implimenting.

### 3.6.4 Profitability of Fertilizer Use

At the commercial price of inorganic fertilizer, the marginal value cost ratio, MVCR, (the measure of fertilizer profitability) is estimated to be 0.81 when maize is valued at farm gate price, 1.32 when maize is valued at lean season market and 2.18 when maize is valued at import parity price (figure 3.2). Assuming positive transaction costs, the MVCR estimates show that, the use of commercial fertilizer in the production of maize is not profitable on average when maize is valued at farm gate price and lean season market price; but profitable when maize is valued at the import parity price. When transaction costs are assumed to be zero however, the use of commercial fertilizer in maize production is profitable on average when maize is valued at lean season market price and import parity price, but still unprofitable when maize is valued at farm gate

[14] The slope coefficient of a parsimonious district-level OLS regression of response rate on yield is also positive and significant (326.84) at the 1% level.

price. The garden level analyses show that, under the assumption of positive transaction costs, fertilizer use is profitable on only less than 1% of gardens when maize is valued at farm gate price; profitable on 17.61% when maize is valued with lean season market price; and profitable on 67% of gardens when maize is valued at import parity price (figure 3.3). Under the zero transaction costs assumption however, the number of gardens on which fertilizer use is profitable increases to 30.78% at farm gate price of maize; 77.96% at lean season market price of maize; and 96.58% at import parity price of maize (figure 3.3).

Generally, the estimates show that the profitability of fertilizer use in maize production is encouraging when transaction costs are assumed to be zero and when maize is valued with the lean season market price or import parity price. However, the assumption of zero transaction cost is not likely to hold in Malawi because of the uncertainty and additional costs associated with use of fertilizer in crop production. Also because ownership of crop storage facilities is very limited (only about 20% of farmers own some storage structure) farmers generally have limited ability to defer the selling of maize to the lean season when prices are relatively higher. Hence the only practical scenario is the assumption of positive transaction cost and the valuation of maize at farm gate price. Under these scenarios, the estimates show that fertilizer use is not profitable on average, and profitable on only less than 1% of gardens.

At the district-level, under the assumption of positive transaction costs, fertilizer use is on average not profitable in all the districts when maize is valued at farm gate, but profitable in Mulanje and Blantyre when maize is valued at lean season market price; and profitable in Dowa, Mangogochi, Chikwawa, Blantyre, Chiradzulu, and Mulanje when maize is valued at import parity price (figure 3.5). Apart from Dowa, which is located in the Central region of the country, all the other districts in which fertilizer use is profitable, are located in the Southern region. Figures 3.4a, 3.4b and 3.4c show that the districts in the southern region have relatively lower NUE but higher maize prices and lower nitrogen prices than the districts in the Northern and Central regions. Hence, the study attributes the higher profitability of fertilizer use in the districts in the Southern region to the fact that farmers in these district face higher maize prices and lower nitrogen prices. This makes sense because southern Malawi has low NUE, low yields and high population density; a condition that results in the area being maize deficit with high maize prices, often leading to maize coming in to Southern Malawi from the central region and Mozambique.

Profitability of fertilizer use can be improved by increasing NUE and/or increasing the maize-nitrogen price ratio. On average, in order for fertilizer to be profitable at current prices, the NUE will have to increase to 28.20kg (137.17%) when maize is valued at farm gate price, and to 17.89kg (50.46%) when maize is valued at lean season market price (figure 3.6). At the garden level, in order for fertilizer use to be profitable, NUE will have to increase by more than 100% on 69.5% of the gardens when maize is valued at farm gate price, and 22% of the gardens when maize is valued at the lean season market price (figure 3.7). Also, NUE will have to increase by 40-100% on about 25.78% of the gardens in order for fertilizer to be profitable when maize is valued with either farm gate price or harvest season price (figure 3.7). These estimates reveal that, in order for the use of fertilizer to be profitable, NUE will have to increase by a large margin. The NUE on experimental plots in Malawi, which is considered to be the maximum attainable response rate, has been estimated to be 17kg (Harou et al., 2015). Hence the study considers the increases in NUE (137.17% and 50.46%) required to make fertilizer use profitable to be impractical.

The production function estimates provide some insights into how NUE can be improved. As indicated in the previous section, compliance with the recommendation for inorganic fertilizer application such as timely application of basal fertilizer and not applying fertilizer beyond the recommended rate has yield-increasing effect. Thus NUE could be improved if farmers comply with these recommendations.

#### 3.6.5 Subsidy and Fertilizer Profitability

The estimates indicate that, as expected, reducing the price of fertilizer via an inorganic fertilizer subsidy, all things being equal, boosts the profitability of the use of fertilizer in maize production. For instance, when maize is valued at farm gate price, 25%, 50%, 75% and 90% fertilizer subsidy increases the average MVCR from 0.81 to 1.02, 1.38, 2.11 and 3.11 respectively (figure 3.8a). In terms of the number of gardens on which fertilizer is profitable, the estimates show that, these rates of subsidy will increase the number of gardens on which fertilizer is profitable from 0.88% to 6.15%, 25.14%, 66.44% and 84.14% respectively (figure 3.8b). Similar effects of fertilizer subsidy on fertilizer profitability were observed when maize is valued at lean season market price and import parity price (figure 3.8a and 3.8b). It is clear from these estimates that even with fertilizer subsidy, the profitability of fertilizer use in the production of maize is still low when maize is sold at the farm gate price, but quite encouraging when maize is sold at the lean season market price and import parity price. This assertion is further highlighted by the break-even rate of subsidy that is estimated to be very high – 72.43% and 41.34% when maize is valued at farm gate price and lean season market price respectively (table 3.4). The estimates of the break-even fertilizer rates mean that, at current NUE and fertilizer prices, inorganic fertilizer would have to be subsidized by 72.43% when maize is valued at farm gate price, and by 41.34% when maize is valued at lean season market price, in order for fertilizer use to be profitable in maize production.

In order to put the effect of the fertilizer subsidy on the profitability of fertilizer use in maize production into perspective, the study compared the cash amount of fertilizer subsidy with how much the average farmer will gain from using subsidized fertilizer in maize production. The study finds that at all rates of fertilizer subsidy, unless farmers are able to store their produce and sell in the lean season, the average farmer is MK 66.16 per kg of subsidized nitrogen better off with the cash equivalent of the subsidy than participating in the subsidy program if maize is valued at the farm gate. If farmers are able to store maize and sell in the lean season however, they will be MK 111.70 per kg of subsidized nitrogen better off with the subsidized inputs than with the cash amount of the subsidy. The study could not account for the opportunity cost and the other operational costs associated with maize production in the estimation, both of which will make the cash equivalent of the subsidy more favorable than the subsidized inputs. Hence although a fertilizer subsidy increases the profitability of fertilizer use, farmers would, on average, be better off with the cash equivalent of the subsidy than with subsidized inputs at current market and agronomic conditions, unless they are able to defer the selling of their output to the lean season.

### 3.6.6 Profitability of Government Recommended Rates of Nitrogen Application

As a final exercise, the study investigates the profitability of fertilizer use at rates recommended by the Ministry of Agriculture and Food Security of Malawi (MoAFS). The government recommended rate of nitrogen application in maize production is 35kg/ha, 69kg/ha or 92kg/ha depending on the geographical location. The corresponding NUE of the nitrogen recommended rate was computed at the garden level using the estimates from the production function. With this NUE and the prices of nitrogen and the various prices of maize, the MVCR of the government recommended rates is computed to be 1.77 at farm gate maize price, 2.89 at the lean season maize price, and 4.71 at import parity maize price (figure 3.9). Thus, compared to the actual rate of nitrogen application, the government rate of application is about 116% to 119% more profitable depending on the price at which maize is valued (figure 3.9). Figure 3.10 also shows that, compared to the actual rate of application, the number of gardens on which fertilizer is profitable is between 26 and 50 percentage points higher. Figure 3.11 reveals that the actual rate of N application on a majority (about 82%) of plots is lower than the government recommended rates. This means that fertilizer profitability can be improved by encouraging farmers to adopt the government recommended rates.

## 3.7 Conclusions and Policy Recommendations

This study uses a two-wave nationally representative household panel data from Malawi to assess the profitability of fertilizer use. Specifically, the study assessed the extent to which fertilizer use in profitable, the effect of subsidy on the profitability of fertilizer use, and the profitability of government recommend fertilizer application rates.

The study adds to the fertilizer profitability literature by controlling for plot-level unobserved heterogeneity; considering all the possible prices that farmers may face in the input and output markets; and by relating the estimates to the geographical targeting of large-scale fertilizer subsidy programs.

The results indicate that, assuming positive transactions costs, an assumption that is likely to hold in Malawi and other parts of SSA, fertilizer use is on average not profitable at commercial price of fertilizer when maize is valued at either the farm gate price or lean season market price. At the garden level, fertilizer use is profitable on less than 1% of gardens when maize is valued at either farm gate price, profitable on only 17.61% of gardens when maize is valued at the lean season market price; and profitable on 67.09% when maize is valued at the import parity price. At the district-level, fertilizer use is not profitable in all the districts of Malawi when maize is valued at farm gate price; and profitable in only two districts (Blantyre and Mulanje) at lean season market price. This low profitability of fertilizer use provides limited incentives to farmers to purchase and use commercial fertilizer in maize production. The study also finds that, in order to make fertilizer more profitable at prevailing market conditions, the current average nitrogen use efficiency of 11.89kg would have to increase by at least 137.17% and by 50.46% if maize output is valued at farm gate price and lean season market price respectively; or fertilizer ought to be subsidized at a rate of at least 72.43% and 41.34% when maize is valued at farm gate price and lean season market price respectively. The study further finds that, at all rates of subsidy, unless farmers are able to store their produce and sell in the lean season, the average farmer is MK 66.16 per kg of subsidized nitrogen better off with the cash equivalent of the subsidy than participating in the subsidy program if maize is valued at the farm gate. If farmers are able to store maize and sell in the lean season however, they will be MK 111.70 per kg of subsidized inputs better off with the subsidized inputs than with the cash amount of the subsidy. Finally, the study finds that, compared to the current rate of nitrogen application, the government recommended rate is 116% to 119% more profitable depending on the price at which maize is valued.

Based on these findings, the study makes the following recommendations. First, in order to improve the profitability of fertilizer use in maize production in Malawi, NUE needs to improve. Applying basal fertilizer within a week after planting and applying organic manure have yield-increasing effects. NUE can therefore be raised by encouraging farmers to comply with these recommendations. Second, the Ministry of Agriculture and Food Security should encourage farmers to increase their current rates of nitrogen application to the government recommended rates in order to improve the profitability of fertilizer use. Third, fertilizer profitability can be improved by encouraging agricultural households to store most of their maize to consume or sell during the lean season when prices are relatively high. This can be done by promoting the adoption of improved grain storage technologies. In addition, farmers are usually compelled to sell their produce soon after harvesting for financial reasons, so another way of encouraging them to store and sell during the lean season would be by providing them with credit that could be paid back later on in the lean season rather than at harvest. Fourth, efforts should be made to reduce the real costs of input supply, through investment in roads, and infrastructure (Jayne et al, 2003).  This will lower commercial fertilizer prices and make it more profitable to use the input. Finally, the study recommends that, in the context of fertilizer profitability, it is also important for the government to consider transferring the cash equivalent to farmers in areas where NUE on maize production is extremely low.  Households in these areas likely would obtain a higher benefit from the cash then they do from subsidized fertilizer.

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Table 3-1 Definition of Variables

| **Variable** | **Definition** |
|---|---|
| N application rate | Nitrogen application rate (Kg/ha) |
| Below recommended N application rate | = 1 if nitrogen application is more than 10% below the recommended application rate |
| Above recommended N application rate | = 1 if nitrogen application is more than 10% above the recommended application rate |
| Applied basal fertilizer on time | = 1 if basal fertilizer was applied within a week after planting |
| Applied organic fertilizer | = 1 if organic fertilizer was applied |
| Seed rate | Seed application rate (Kg/ha) |
| Used hybrid seed | = 1 if hybrid seed was used |
| Pure stand | = 1 if plot was pure stand |
| Plot size | GPS-measured plot size (ha) |
| Labor | Days of labor (family, hired and exchange) used for non-harvesting activities |
| Soil is of good quality | = 1 if plot is of good soil quality; 0 otherwise |
| Soil is of fair quality | = 1 if plot is of poor soil quality; 0 otherwise |
| Plot is not plot | = 1 if plot is not flat; 0 otherwise |
| Plot is swampy | = 1 is plot is swampy; 0 otherwise |
| Soil is sandy-clay | = 1 if soil is sandy-clay; 0 otherwise |
| Plot show signs of erosion | = 1 if plot showed signs of erosion; 0 otherwise |
| Female plot manager | = 1 if plot manager is female; 0 otherwise |
| Age of plot manager | Age of plot manager (years) |
| Years of education of plot manager | Years of education of plot manager |
| African Adult Male Equivalent | African Adult Male Equivalent household size |
| Dependency ratio | Dependency (child and adult) ratio |
| Distance to boma | Distance to district capital (Km) |
| Index of ownership of agricultural tools | $1^{st}$ principal component analysis of agricultural tools owned by the household |
| Index of ownership of durable good | $1^{st}$ principal component analysis of durable assets owned by the household |
| Annual mean rainfall | Avg 12-month total rainfall(mm) for July-June |
| Annual mean temperature | Annual mean temperature ($^{o}C$*10) |

Table 3-2 Descriptive Statistics

| | Pooled | | 2010 | | 2013 | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Maize yield (Kg/ha) | 1,401.659 | 1,071.563 | 1,240.611 | 920.973 | 1,536.273*** | 1,166.269 |
| Nitrogen application rate (Kg/ha) | 46.014 | 44.657 | 49.181 | 44.595 | 43.367*** | 44.599 |
| Below recommended nitrogen application rate (1/0) | 0.791 | 0.412 | 0.771 | 0.426 | 0.808*** | 0.400 |
| Above recommended nitrogen application rate (1/0) | 0.143 | 0.356 | 0.161 | 0.372 | 0.129*** | 0.341 |
| Applied basal fertilizer on time (1/0) | 0.284 | 0.456 | 0.355 | 0.482 | 0.224*** | 0.424 |
| Applied inorganic fertilizer twice (1/0) | 0.746 | 0.437 | 0.778 | 0.422 | 0.720*** | 0.448 |
| Fertilizer used is basal fertilizer | 0.507 | 0.500 | 0.484 | 0.500 | 0.527*** | 0.499 |
| Applied organic fertilizer (1/0) | 0.162 | 0.364 | 0.131 | 0.335 | 0.187*** | 0.385 |
| Seed rate (Kg/ha) | 25.019 | 21.447 | 22.814 | 25.273 | 26.863*** | 17.437 |
| Used hybrid seed (1/0) | 0.406 | 0.492 | 0.430 | 0.496 | 0.386*** | 0.489 |
| Pure stand (1/0) | 0.467 | 0.500 | 0.511 | 0.499 | 0.431*** | 0.499 |
| Plot size (ha) | 0.409 | 0.265 | 0.422 | 0.255 | 0.398*** | 0.272 |
| Labor (days) | 135.580 | 98.763 | 119.599 | 80.505 | 148.937*** | 109.886 |
| Soil is of good quality (1/0) | 0.444 | 0.496 | 0.457 | 0.498 | 0.433 | 0.495 |
| Soil is of fair quality (1/0) | 0.420 | 0.495 | 0.409 | 0.492 | 0.429 | 0.497 |
| Plot is sloppy (1/0) | 0.449 | 0.497 | 0.451 | 0.498 | 0.446 | 0.496 |
| Plot is swampy (1/0) | 0.159 | 0.362 | 0.158 | 0.358 | 0.160 | 0.365 |
| Soil is sandy clay (1/0) | 0.548 | 0.495 | 0.554 | 0.495 | 0.542 | 0.496 |
| Plot show signs of erosion (1/0) | 0.378 | 0.486 | 0.380 | 0.489 | 0.376 | 0.482 |
| Female plot manager (1/0) | 0.309 | 0.457 | 0.297 | 0.453 | 0.318 | 0.460 |
| Age of plot manager (years) | 42.608 | 15.184 | 41.783 | 14.927 | 43.298*** | 15.353 |
| Years of education of plot manager | 4.822 | 3.840 | 4.735 | 3.830 | 4.895 | 3.847 |
| African Adult Male Equivalent | 3.961 | 1.648 | 3.843 | 1.597 | 4.059*** | 1.683 |
| Dependency ratio (%) | 122.008 | 90.398 | 124.345 | 92.688 | 120.054*** | 88.426 |
| Distance to boma (Km) | 38.023 | 27.151 | 49.483 | 27.265 | 28.443*** | 23.413 |
| Index of ownership of agricultural tools | 0.289 | 1.354 | 0.508 | 1.695 | 0.105*** | 0.934 |
| Index of ownership of durable goods | -0.793 | 1.552 | -0.568 | 1.573 | -0.981*** | 1.509 |
| Annual mean rainfall (mm) | 827.249 | 80.186 | 830.507 | 86.039 | 824.526*** | 74.715 |
| Annual Mean Temperature (°C * 10) | 215.331 | 17.816 | 215.482 | 18.045 | 215.205 | 17.625 |

*** implies significant difference in mean between 2013 and 2010 at the 1% level

Table 3-3 Maize Production Function

| | | | | | | Multilevel models (Level 1 = Plot) | |
|---|---|---|---|---|---|---|---|
| VARIABLES | OLS | EA FE | District FE | HH FE | Garden FE | Level 2 = HH | Level 2 = Garden |
| N application rate (Kg/ha) | 12.092*** | 10.637*** | 11.284*** | 9.237*** | 11.213*** | 11.552*** | 11.887*** |
| | (1.698) | (1.741) | (1.678) | (2.248) | (3.174) | (1.484) | (1.521) |
| Nitrogen application rate (Kg/ha) squared | -0.017 | -0.015 | -0.016 | -0.014 | -0.027 | -0.017* | -0.018* |
| | (0.011) | (0.011) | (0.010) | (0.013) | (0.016) | (0.009) | (0.009) |
| Below recommended N application rate | 59.641 | -4.043 | 21.955 | -14.258 | 57.552 | 69.972 | 82.740 |
| | (83.920) | (83.399) | (83.242) | (87.246) | (100.810) | (76.992) | (78.777) |
| Above recommended N application rate | -281.236*** | -214.159** | -240.122*** | -199.043** | -236.136*** | -211.968** | -233.993*** |
| | (93.450) | (87.359) | (86.948) | (92.964) | (62.194) | (84.074) | (88.874) |
| Applied basal fertilizer on time | 153.624*** | 114.642*** | 114.864*** | 184.009*** | 171.070** | 172.323*** | 169.239*** |
| | (39.746) | (40.853) | (41.541) | (66.360) | (78.907) | (40.290) | (36.331) |
| Fertilizer used is basal fertilizer | 194.653*** | 224.489*** | 206.447*** | 196.515*** | 259.993*** | 180.716*** | 182.223*** |
| | (38.478) | (36.026) | (37.399) | (49.299) | (73.855) | (34.260) | (33.186) |
| Applied organic fertilizer | 132.084** | 135.516*** | 132.407*** | 121.343** | 87.521** | 136.256*** | 126.458*** |
| | (51.262) | (43.187) | (47.636) | (52.494) | (36.686) | (42.020) | (40.595) |
| Seed rate (Kg/ha) | 3.769*** | 3.314*** | 3.164*** | 3.651*** | 2.513* | 3.625*** | 3.453*** |
| | (0.920) | (0.870) | (0.892) | (0.951) | (1.293) | (0.809) | (0.789) |
| Used hybrid seed | 31.985 | 38.291 | 26.574 | 51.413 | 136.536* | 30.901 | 40.850 |
| | (33.965) | (29.982) | (33.007) | (38.839) | (69.693) | (30.243) | (30.724) |
| Pure stand | -86.076** | -174.341*** | -175.919*** | -191.329*** | -210.800*** | -109.635*** | -101.360*** |
| | (40.030) | (36.081) | (34.995) | (42.867) | (48.028) | (31.010) | (30.209) |
| Plot size (ha) | -676.112*** | -883.008*** | -894.862*** | -1,401.012*** | -1,800.821*** | -916.596*** | -847.798*** |
| | (222.339) | (235.539) | (214.805) | (350.108) | (395.619) | (189.547) | (183.287) |
| Plot size (ha) squared | 193.891 | 275.557* | 273.539* | 581.543** | 752.706** | 344.274*** | 286.124** |
| | (146.553) | (163.325) | (152.918) | (259.038) | (314.832) | (130.718) | (127.525) |
| Labor (days) | 0.925*** | 0.913*** | 0.934*** | 0.952*** | 0.962*** | 0.942*** | 0.950*** |
| | (0.209) | (0.206) | (0.207) | (0.268) | (0.282) | (0.197) | (0.183) |
| Soil is of good quality | 283.499*** | 219.820*** | 239.698*** | 168.253*** | 178.885** | 253.805*** | 259.843*** |
| | (50.273) | (50.062) | (48.692) | (54.691) | (75.471) | (41.783) | (41.783) |
| Soil is of fair quality | 173.437*** | 147.593*** | 156.578*** | 181.907*** | 230.479*** | 179.355*** | 179.136*** |
| | (50.434) | (43.679) | (44.756) | (49.679) | (62.539) | (40.327) | (40.557) |
| Plot is not flat | -47.802 | -44.742 | -41.290 | -76.431* | -78.986 | -59.257* | -53.645* |
| | (35.259) | (34.091) | (35.148) | (39.650) | (66.640) | (31.338) | (31.160) |
| Plot is swampy | -5.287 | -33.823 | -8.920 | -83.808 | -115.656 | -32.024 | -26.390 |
| | (38.283) | (37.309) | (35.238) | (52.386) | (89.498) | (40.500) | (39.466) |
| Soil is sandy clay | 25.051 | 33.122 | 33.361 | -13.825 | -8.740 | 24.675 | 29.723 |
| | (35.023) | (33.549) | (31.709) | (38.385) | (57.240) | (30.402) | (29.994) |
| Plot show signs of erosion | 38.679 | -11.732 | -15.097 | 5.421 | 46.803 | 31.250 | 41.151 |
| | (46.275) | (43.577) | (42.716) | (53.265) | (45.854) | (36.397) | (34.315) |
| Female plot manager | -102.625*** | -107.605*** | -90.399** | -150.468** | -198.198** | -111.814*** | -113.273*** |
| | (36.295) | (36.724) | (35.365) | (63.280) | (82.736) | (34.716) | (32.751) |
| Age of plot manager | -1.483 | -0.993 | -1.201 | 2.853 | 0.612 | -0.704 | -1.126 |
| | (1.377) | (1.275) | (1.285) | (1.939) | (2.211) | (1.185) | (1.106) |
| Years of education of plot manager | 13.855*** | 8.181* | 10.930** | 8.614 | -7.623 | 10.638** | 10.353** |
| | (5.201) | (4.752) | (4.830) | (10.485) | (12.591) | (5.020) | (4.674) |
| African Adult Male Equivalent | -5.412 | -0.071 | -2.932 | 10.825 | 29.695 | -5.356 | -5.070 |
| | (13.647) | (14.650) | (13.647) | (27.334) | (38.042) | (12.150) | (10.909) |
| Dependency ratio | 0.289 | 0.245 | 0.215 | 0.226 | 0.046 | 0.298 | 0.249 |
| | (0.195) | (0.188) | (0.183) | (0.286) | (0.272) | (0.197) | (0.186) |
| Distance to boma | 0.481 | -0.455 | -0.354 | -0.809 | -0.219 | 0.068 | 0.373 |
| | (0.803) | (0.885) | (0.896) | (0.983) | (1.314) | (0.616) | (0.568) |
| Index of ownership of agricultural tools | 77.715*** | 52.832*** | 67.763*** | -6.816 | -7.012 | 56.861*** | 68.958*** |
| | (19.448) | (13.962) | (17.097) | (19.674) | (28.193) | (14.832) | (13.108) |
| Index of ownership of durable goods | 88.175*** | 98.621*** | 92.435*** | 83.865*** | 108.644*** | 92.980*** | 93.727*** |
| | (15.353) | (15.597) | (15.075) | (27.362) | (30.276) | (13.880) | (12.545) |
| Annual mean rainfall(mm) | 0.815** | 1.472 | 0.903 | 3.411* | 3.403 | 1.049*** | 1.006*** |
| | (0.374) | (1.116) | (0.599) | (1.871) | (3.007) | (0.250) | (0.236) |
| Annual mean temperature (°C * 10) | -8.853*** | -5.212 | -4.313* | -10.718 | -17.927 | -7.751*** | -7.841*** |
| | (1.897) | (3.797) | (2.587) | (6.943) | (12.535) | (1.274) | (1.204) |
| Year (2013) | 347.955*** | 307.908*** | 313.956*** | 272.768*** | 263.957*** | 317.304*** | 317.289*** |
| | (40.732) | (42.329) | (43.804) | (48.234) | (45.960) | (33.288) | (30.993) |
| Agro-ecological zone fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | 1,662.699*** | 810.346 | 980.193 | 524.097 | 2,302.636 | 1,424.072*** | 1,428.150*** |
| | (598.780) | (1,294.931) | (867.096) | (2,492.269) | (4,859.146) | (409.097) | (380.119) |
| Observations | 4,913 | 4,913 | 4,913 | 4,913 | 4,913 | 4,913 | 4,913 |
| R-squared | 0.283 | 0.246 | 0.318 | 0.226 | 0.247 | -- | -- |
| Number of groups | -- | 194 | 26 | 2,135 | 3,365 | 2,135 | 3,365 |

Robust standard errors in parentheses. EA = Enumeration area; HH = Household.
***, **, and * imply significant at 1%, 5% and 10% levels respectively

Table 3-4 Break-even Subsidy Rate for Fertilizer profitability (i.e. rate of subsidy at which fertilizer use is just profitable)

| **Maize price** | **Break-even fertilizer subsidy rate (%)** |
|---|---|
| Farm gate price | 72.43 |
| Lean season market price | 41.34 |

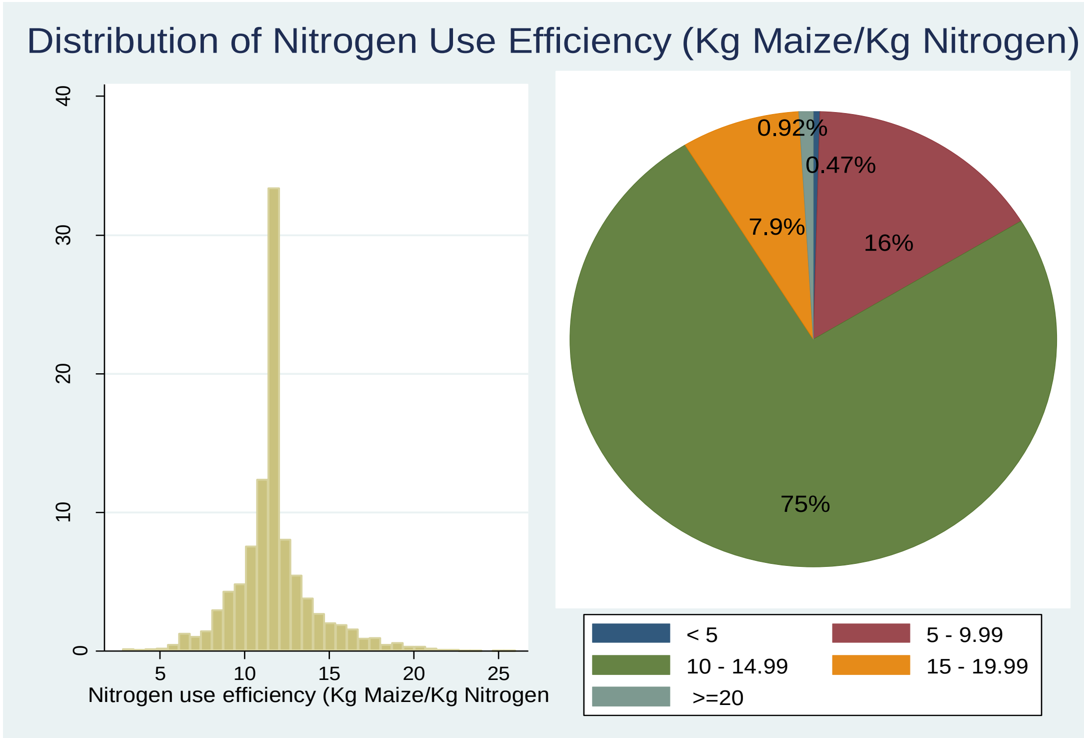



Figure 3-1 Distribution of Maize Response Rate to Fertilizer Based on Multilevel Model (Level 1 = plot; Level 2 = garden)

Mean: 11.82; Minimum: 2.82; Maximum: 25.98; Standard deviation: 2.42

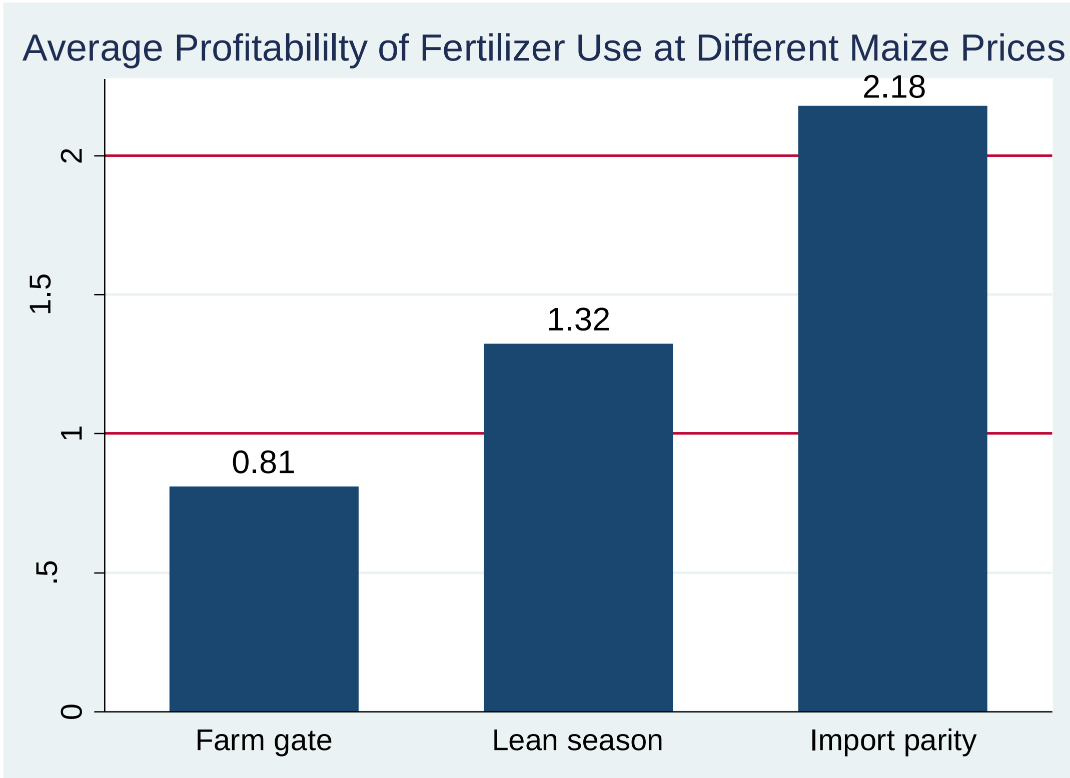



Figure 3-2 Average Profitability of Fertilizer Use at Different Prices of Maize

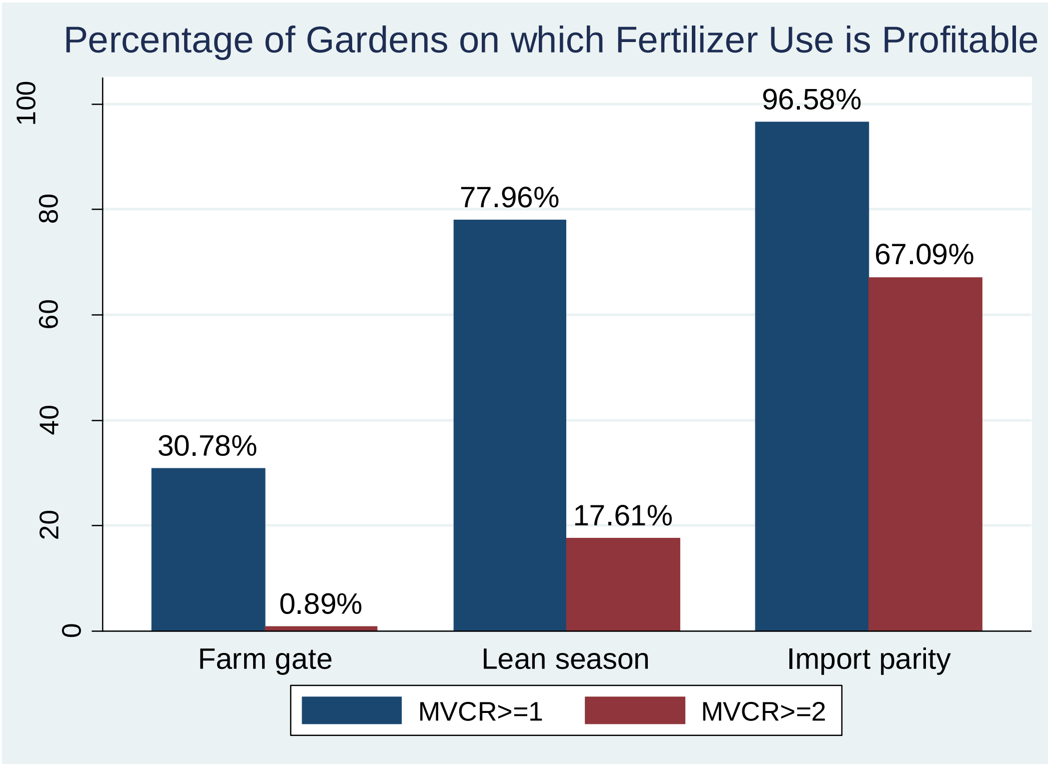
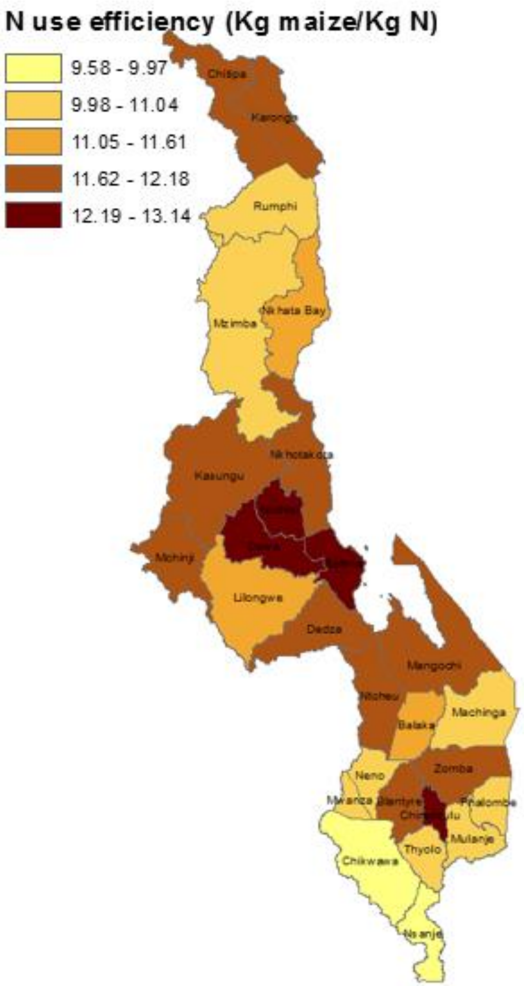
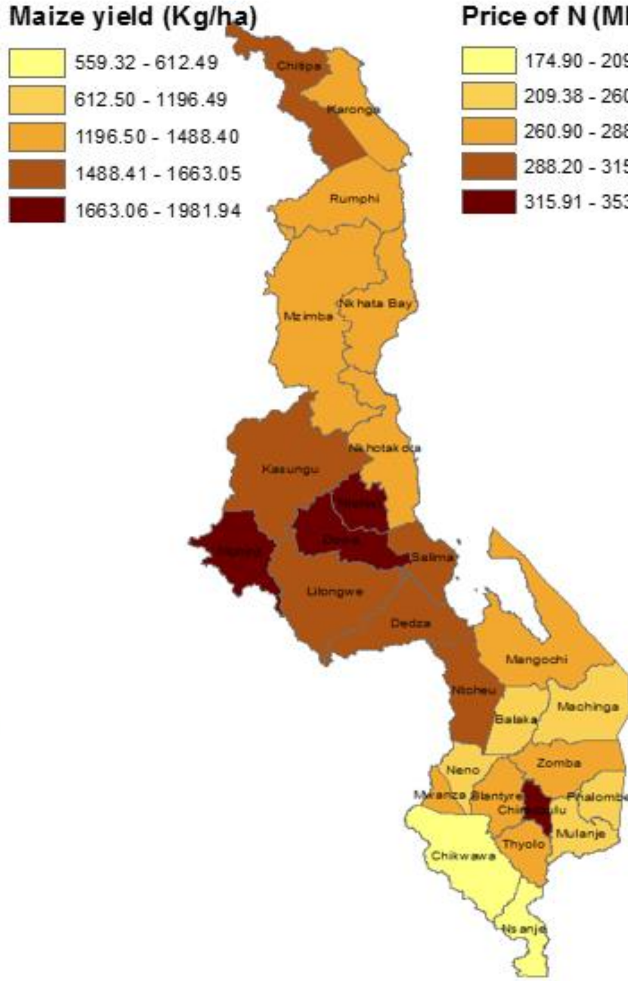



Figure 3-3 Percentage of gardens on which Fertilizer Use is Profitable at Difference Maize Prices



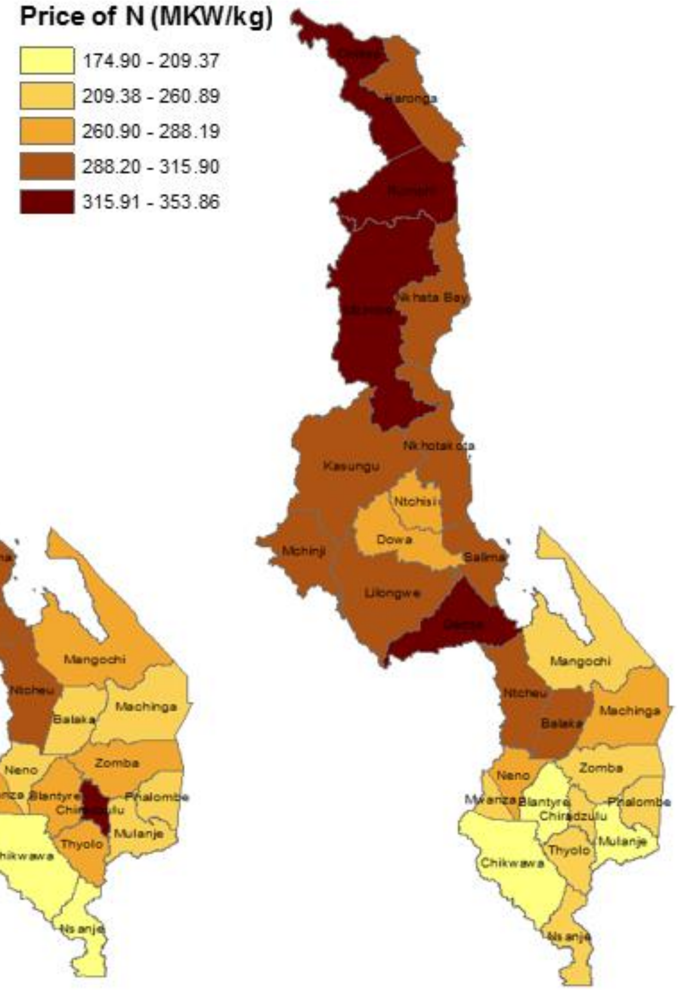




Figure 3-4a Spatial Distribution of Fertilizer Use Efficiency

Figure 3-4b Spatial Distribution of Maize Yield

Figure 3-4c Spatial Distribution of N Price

A. Farm gate maize price

B. Lean season market price of maize

C. Import parity price of maize

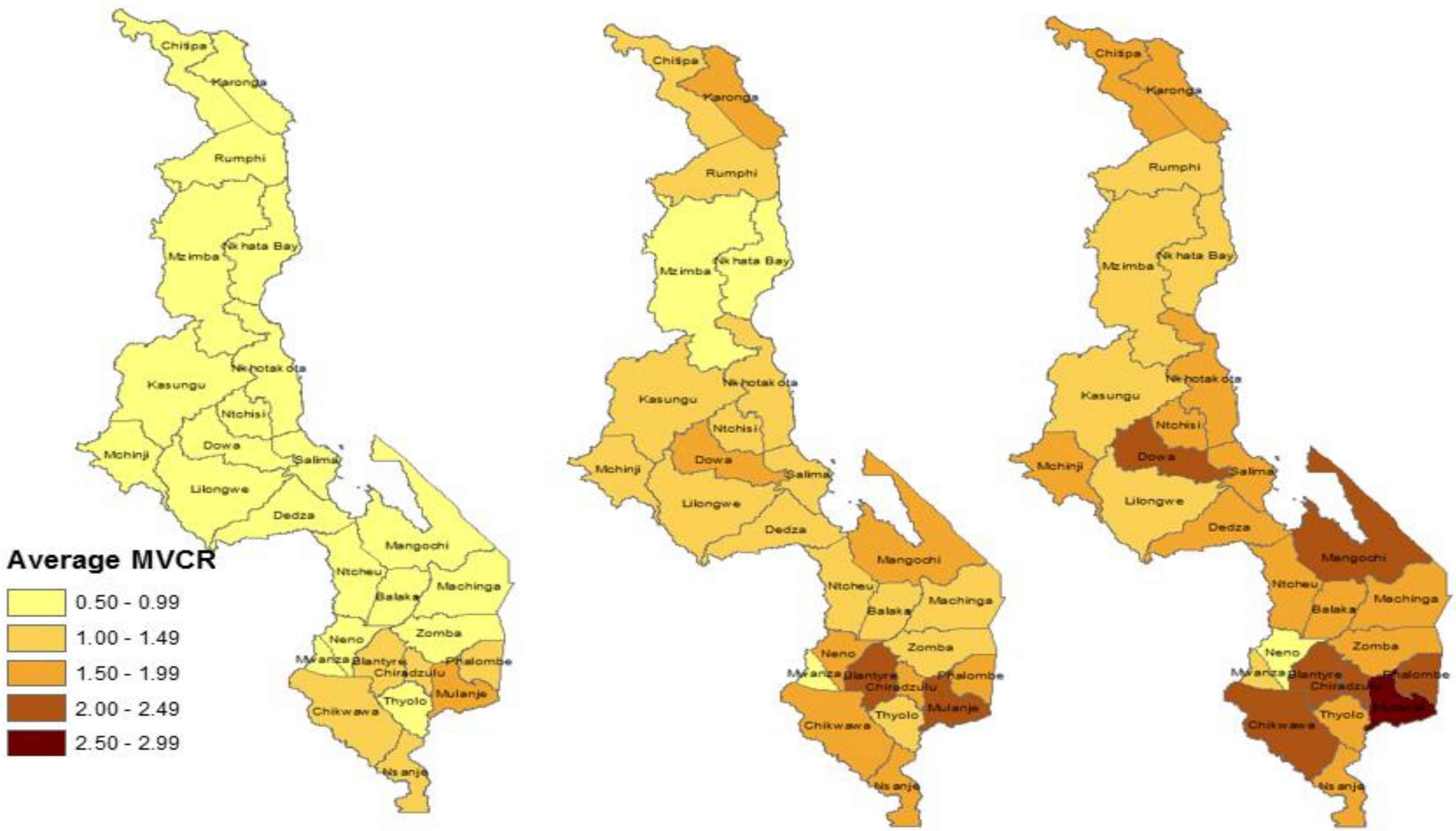



Figure 3-5 Spatial Distribution of Profitability of Fertilizer Use at Different Prices of Maize

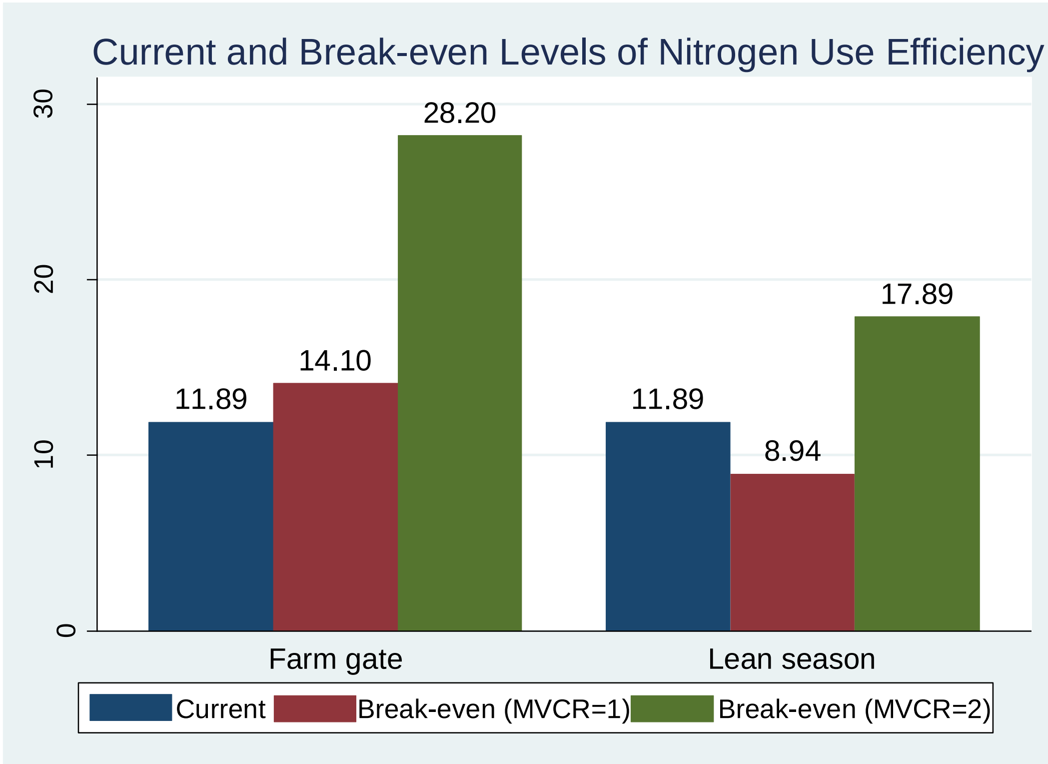



Figure 3-6 Current and Optimal Levels of Nitrogen Use Efficiency at Different Prices of Maize

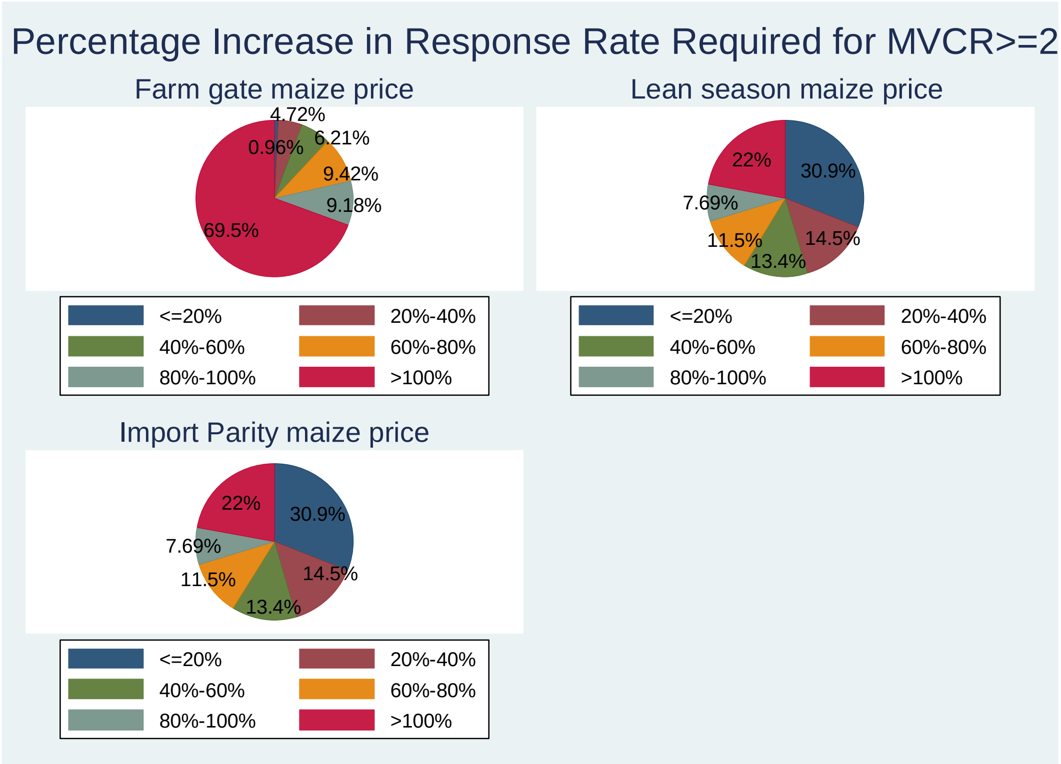



Figure 3-7 Percentage Increase in Response Rate Required for MVCR>=2 at Different Prices of Maize

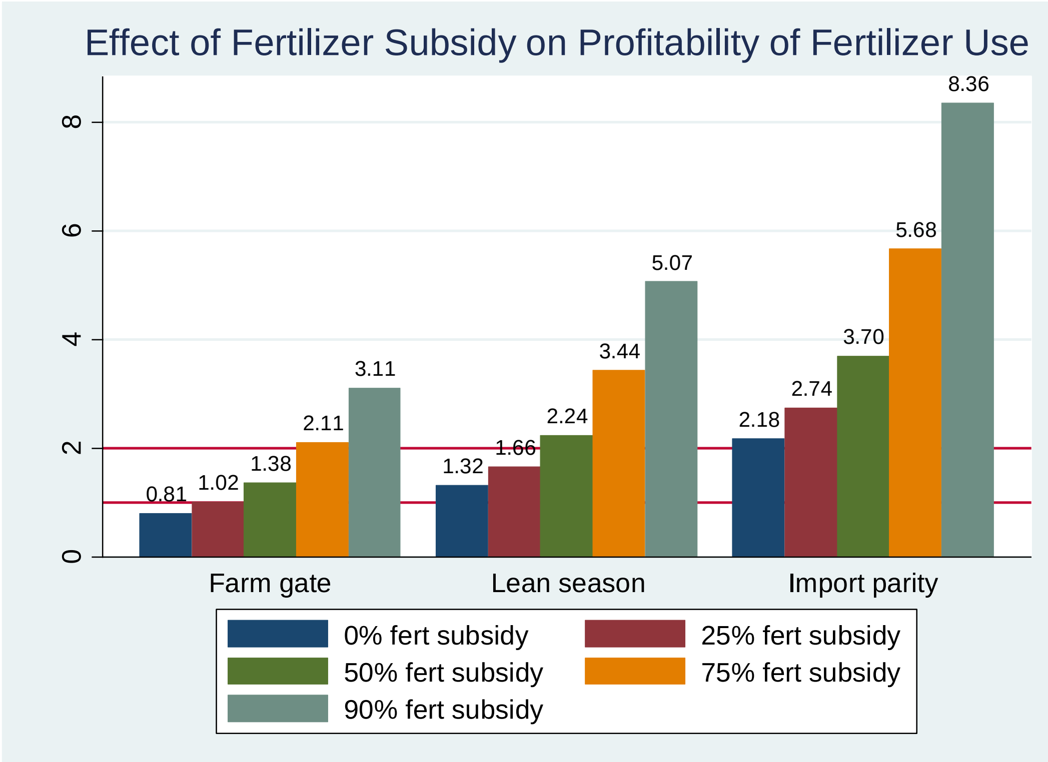



Figure 3-8a Effect of Fertilizer Subsidy on Profitability of Fertilizer Use (MVCR) at Different Prices of Maize

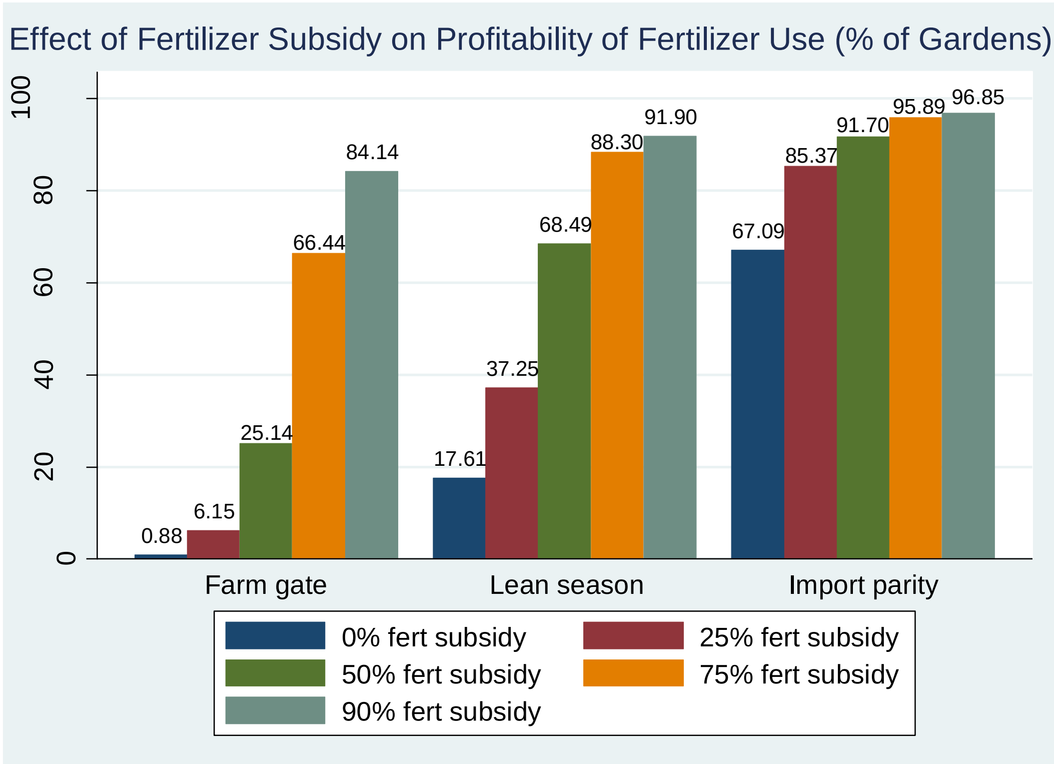



Figure 3-8b Effect of Fertilizer Subsidy on Profitability of Fertilizer Use (% of gardens) at Different Prices of Maize

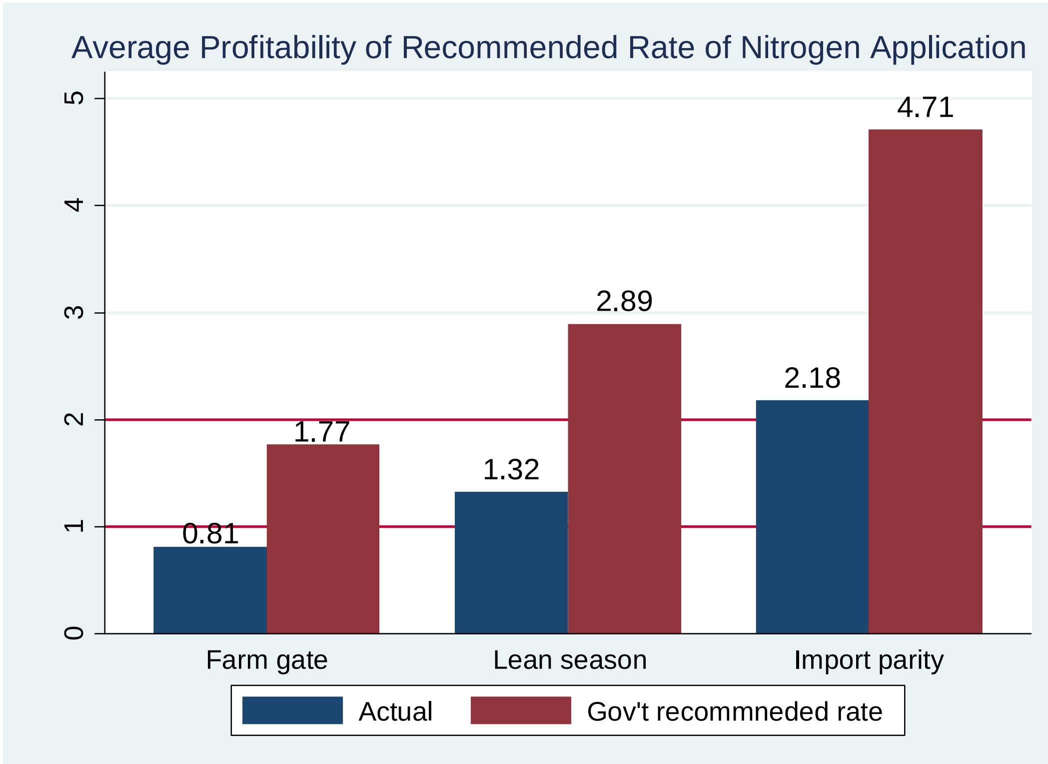



Figure 3-9 Average Profitability of Government Recommended Rate of Fertilizer Application at Different Prices of Maize

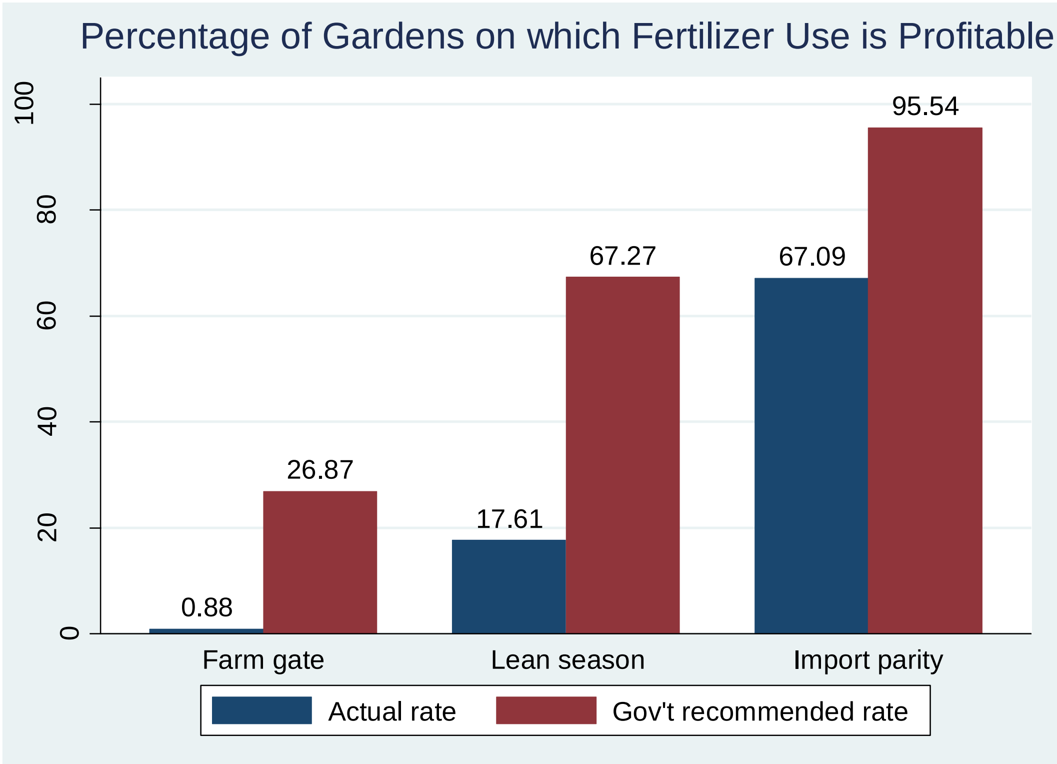



Figure 3-10 : Average Profitability of Government Recommended Rate of Fertilizer Application at Different Prices of Maize

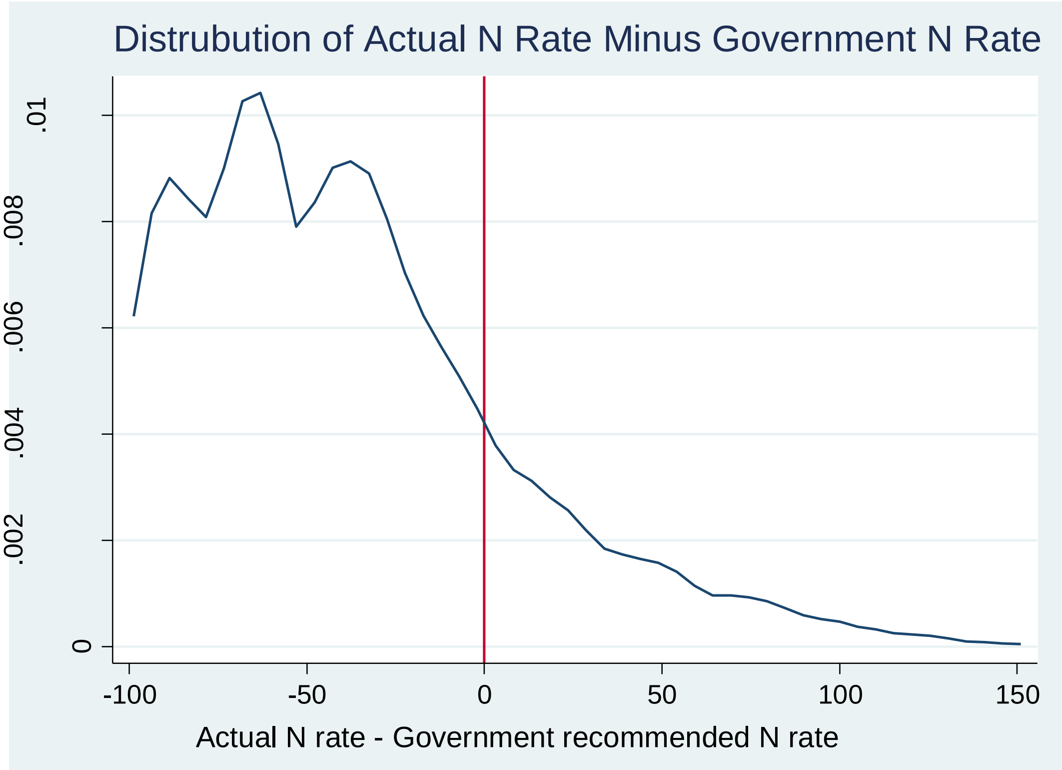



Figure 3-11 Distribution of Recommended Nitrogen Application Rate Minus Actual Nitrogen Application Rate

# CHAPTER 4: SHOULD FARM INPUT SUBSIDY PROGRAMS TARGET POOR OR NON-POOR FARMERS?

## 4.1 Introduction

Farm input subsidy programs have been the mainstay agricultural policy in many countries in Sub-Saharan African (SSA) since the 1960s (Kherellah et al., 2002; Jayne and Rashid, 2013). From the 1960s through to the 1980s, the programs were implemented as universal (i.e. accessible to all farmers), and were supported by international donors to help overcome market failures in input and finance markets (Jayne and Rashid, 2013). Although the universal subsidy programs succeeded in raising input use and food production, they were very expensive and thus caused significant fiscal and macro-economic problems (Banful, 2011; Dorward et al., 2008). The value of the output produced using subsidized inputs fell short of the costs of the programs in many SSA countries (Howard and Mungoma, 1997; World Bank, 2007; Jayne and Rashid 2013). Moreover, evidence suggests that the universal programs favored relatively wealthier, well connected and larger-scale farmers at the expense of smallholder, poor farmers (Banful, 2011). Beginning from the early 2000s, targeted farm input subsidy programs (TFISPs) were introduced to address the shortcomings of the universal ones. TFISPs are supposed to: 1) target poor and vulnerable farmers who are otherwise not available to acquire inputs like inorganic fertilizer and improved seeds at commercial prices;

2) support the development of existing private input supply systems; and 3) devise appropriate exit strategies for the beneficiaries of the program (Morris et al., 2007; Baltzer and Hansen, 2011). If properly implemented, TFISPs could be expected to be more economically efficient and have greater impacts on food production compared to the universal subsidies programs, albeit cost of targeting as a counterweight.

The impact of TFISPs, like other targeted development programs, depends integrally on the effectiveness of the targeting process, the process used in identifying and reaching beneficiaries. Targeting plays a crucial role in that it determines the beneficiaries of the program, the amount of inputs they receive, and hence how the inputs are used. The eventual impacts of the program are therefore closely linked to the quality of the targeting process. That notwithstanding, the weight of the empirical evidence suggests that targeting of most TFISPs in SSA has not been effective (Kilic et al., 2014; Ricker-Gilbert et al., 2013; NSO, 2012). The goal of this study is to help improve the targeting of TFISPs by providing guidance for deciding on whether programs should be targeted at poor or non-poor farmers , using a two-wave panel data from Malawi[15].

Aside from the cost of targeting, the decision of whether a subsidy should be targeted at poor or non-poor farmers depends on three factors. The first factor is the objective of the programs. Officially, TFISPs in SSA aim at achieving two main goals:

[15] Targeting is made up of two processes: 1) identification of the targets i.e. the category of people to be targeted, and 2) identification of the most appropriate targeting method i.e. the method used in delivering the inputs to beneficiaries. Examples of targeting method include universal targeting, community-based targeting, proxy means tests etc. The effectiveness of both processes are equally important in ensuring successful targeting. This study focusses on the first process, leaving the second process for future studies.

1) ensuring household food security and national food sufficiency through increased food production; and 2) reducing poverty by increasing the income levels of beneficiaries. These goals have different implications for targeting. The objective of ensuring household food security and national food sufficiency suggests that the program should be targeted at productive farmers in areas (regions, districts and communities) with high productivity potential. In theory, targeting productive farmers would maximize food availability not only for beneficiaries of the programs but also for non-beneficiaries through the lowering of food prices as a result of increased production. The poverty reduction objective on the other hand suggests that the program be targeted at poor farmers. Therefore, targeting poor farmers with the aim of achieving both the food security and the poverty reduction objectives, as most governments of SSA countries with TFISP are currently doing, suggests that poor farmers are implicitly assumed to be at least as productive as non-poor farmers. The validity or otherwise of this implicit assumption is critical for effective targeting of TFISPs. If poor farmers are at least as productive as non-poor farmers, both objectives can be achieved by targeting poor farmers. However, if non-poor farmers tend to be more productive than poor farmers, TFISPs would have to focus on either the food security objective or the poverty reduction objective because the target populations that maximize the achievement of both objectives do not coincide.

The second factor on which the decision to target TFISPs depends is the difference between poor and non-poor farmers in terms of the efficiency with which subsidized inputs are utilized. There is a long literature that suggests that poor farmers are efficient in the use of farm inputs in crop production. Schultz (1964) who argued that because traditional farmers mainly use their own resources and are experienced in doing so, they are able to make the most efficient use of resources in their environment. Compared to non-poor farmers, however, poor farmers may be less productive because non-poor farmers are usually better equipped to use complimentary inputs such as hired labor, pesticides, organic matter, and also have the ability to acquire or rent in plots of better soil quality. All of these advantages boost the efficiency with which inorganic fertilizer and other subsidized inputs can be used. Thus the assumption that poor farmers are at least as productive as non-poor farmers is an empirical matter.

The third factor governing the value of targeting is the difference between poor and non-poor farmers in terms of the extent to which the use of subsidized farm inputs crowds out the demand for commercial farm inputs. Previous research reports that subsidized farm inputs crowds out commercial farm inputs (Mason and Jayne, 2013; Ricker-Gilbert et al. 2011; Xu et al., 2009). Such crowding out undermines the viability of the private sector and reduces the contribution of the fertilizer subsidy programs to total fertilizer use as well as the overall net impact of such programs on food production and levels of farm income (Dorward et al., 2008; Ricker-Gilbert, 2011; Shively and Ricker-Gilbert, 2013). By virtue of higher income, non-poor farmers are likely to purchase higher quantities of commercial fertilizer and are therefore likely to have higher levels of crowding out than poor farmers. The higher level of crowding out among non-poor farmers suggests a possible trade-off between targeting non-poor farmers and targeting to poor farmers, thereby undermining the propensity to target non-poor farmers.

With these considerations in mind, the research question that this study seeks to answer is: *Is there any gain in yield for targeting non-poor farmers instead of poor and ultra-poor farmers after accounting for the potential difference in input use efficiency* *and crowding out across poverty groups?* The steps involved in the empirical approach used in answering this question will help clarify issues such as whether the poverty and food security goals of TFISPs can be achieved together by targeting poor farmers, whether or not poor farmers are as productive as non-poor farmers, and whether crowding out varies significantly across poor and non-poor farmers. By answering these questions, the study provides an empirical standpoint for the targeting discourse that has in the past been based mostly on anecdotal evidence.

Targeting of farm input subsidy programs in SSA has been widely discussed in the literature (Doward and Chirwa, 2013; Ricker-Gilbert and Jayne, 2012; Ricker-Gilbert and Jayne, 2016). However, many of these studies either provide a general discussion of the issues in targeting without any empirical analysis or discuss some aspects of targeting but go on to estimate some other impacts of farm input subsidy programs. Thus, the literature on empirical studies for which targeting of farm input subsidy programs is the central focus is very sparse. As far as this study is concerned, Kilic et al. (2014), Houssou and Zeller (2010) and Basurta et al (2015) are the only studies that empirically addressed issues related to the targeting of farm input subsidy programs in SSA. Houssou and Zeller (2011) assessed and compared the target, impact and cost-effectiveness of proxy means tests (an indicator-based targeting system) to universal and community-based targeting systems using quintile regressions and nationally representative data from Malawi's Second Integrated Household Survey (IHS2). The study finds that although the proxy means tests is associated with relatively higher administrative costs, its overall benefits in targeting poor and smallholder farmers outweighs the cost involvements; and the proxy means tests tends to be potentially more target, cost and impact efficient than the universal and community-based targeting systems. Kilic et al. (2014) analyzed the overall performance of the decentralized targeting of Malawi's farm input subsidy program using nationally representative data of the 2009-10 agricultural season by decomposing the national targeting performance into district and community level components: inter-district, intra-district inter-community, and intra district intra-community components. The authors find that Malawi's farm input subsidy program is not poverty targeted and that the national government, districts, and communities are nearly uniform in their failure to target the poor, with any minimal targeting (or mis-targeting) overwhelmingly materializing at the community level. Classifying farmers into kins and non-kins of chiefs (traditional leaders), Basurto et al. (2016) used a five-wave panel from Malawi to explore the trade-off between the informational/accountability advantages of decentralized targeting systems and its associated elite capture in the context of large scale subsidy programs in Malawi decentralized to chiefs. The authors find evidence of elite capture and poverty-mistargeting for the subsidy programs considered; and also find that the poverty-mistargeting by chiefs is partly due to productive efficiency considerations. This study contributes to the targeting discourse by seeking to empirically estimate the overall gain in yield for targeting non-poor farmers instead of poor farmers, after accounting for the potential difference in input use efficiency and crowding out across poverty groups.

The results of this study indicate that non-poor farmers are significantly more productive than poor and ultra-poor farmers, but crowding out of commercial fertilizer by subsidized fertilizer also tends to be significantly higher among non-poor farmers, suggesting a trade-off between targeting non-poor farmers and targeting poor farmers. Further analysis of the trade-off however indicates that targeting non-poor farmers instead of poor farmer, after accounting for the significant differences in productivity and crowding out, will result in an overall yield gain of 3.136kg or 4.330kg per kilogram of nitrogen. The rest of the chapter is organized as follows: section 4.2 provides background information for targeting of FISP; the conceptual framework and empirical models are presented in sections 4.3 to 4.5; sections 4.6 and 4.7 are about the data used in the analyses and the how farmers were classified into poverty groups respectively; the results are presented in section 4.8; and section 4.9 concludes the chapter.

## 4.2 Background: Targeting of Malawi's Farm Input Subsidy Program

In terms of scope and coverage, Malawi's targeted farm input subsidy program (FISP) is perhaps the most well-known TFISP in Africa. It currently provides inorganic fertilizers and improved maize and legume seeds to over 50% of rural, smallholder farmers at hugely subsidized prices (about 95% subsidy). Each beneficiary is entitled to 50kg of Urea; 50kg of NPK 23:21:0; 5kg of improved maize seed or 10kg of open pollinated variety maize seed; and a kilogram of legume seed (Kilic et al., 2014). Beneficiaries receive coupons that are to be redeemed for inputs at subsidized prices at participating retailers who in turn redeem the coupons to the government, receiving the full commercial price minus the subsidized price. The coupons are distributed to beneficiaries in a decentralized manner. Officials of the Ministry of Agriculture and Food Security (MoAFS) allocate coupons to districts and Extension Planning Areas (EPAs) where representatives are subsequently mandated to redistribute the coupons to selected villages and communities within the district and EPAs. Community leaders and local authorities of the selected villages and communities are then authorized to identify and distribute the coupons to beneficiary households using a predefined criteria. The predefined criteria involves “resource-poor” Malawians who own a piece of land and are resident in the village/community, with special consideration to guardians looking after physically challenged persons, child-headed, female-headed and orphan-headed households (MoAFS, 2009; Chirwa et al. 2011). According to Dorward and Chirwa (2013), the criteria for the distribution of coupons to districts and EPAs is “very opaque” although it is supposed to be in line with a number of household characteristics.

Among other things, the difficulty in clearly establishing measures for applying these criteria and the fact that eligible households exceed the number of available coupons results in community leaders and village authorities not consistently applying the set criteria. Hence coupon allocation at both the district/EPA and village/community levels may be based on unofficial criteria such as political support at the district level; and relationship to community leaders and local authorities, length of residence, and social and/or financial status of households at the community level (Banful, 2011; Ricker-Gilbert et al., 2011). Accordingly, the targeting of FISP has been ineffective. Studies on participation in FISP reveal that subsidized inputs do not always get to the intended beneficiaries (Ricker-Gilbert et al., 2011; Chibwana et al., 2012; Kilic et al., 2014; Houssou and Zeller, 2011; Dorward et al., 2008). Ricker-Gilbert et al. (2011) and Chibwana et al. (2012) observed that male-headed households and relatively wealthier farmers, rather than female-headed households and poor farmers, are more likely to access subsidized inputs. Kilic et al. (2014) reports that neither the poor nor the rich are exclusively targeted by the program, but rather the middle of the income distribution if there is any targeting at all. The program's coverage and leakage rates[16] of 35% and 65% respectively in 2004/2005; 46% and 54% respectively in 2006/07; and 57.9% and 52%[17] respectively in 2009/10 also lend credence to the shortcomings in the targeting process (Kilic et al., 2014; Houssou and Zeller, 2011; Dorward et al., 2008).

The weaknesses in the targeting process has likely undermined the impacts of FISP on productivity, staple food prices and poverty. Although evidence (Holden and Lunduka, 2010; Chibwana et al. 2012) suggest that FISP has had positive impact on maize productivity, given the size, scope and cost of the program, the effect is only modest when comparing the benefits of the program against the costs (Ricker-Gilbert et al., 2013). The modest effect of the program on maize productivity can, *inter alia*, be linked to the weaknesses in the targeting process with the possible explanation being that participation of farmers who could make efficient use of the subsidized inputs was limited. FISP, like other large-scale farm input subsidy programs, is expected to significantly reduce the retail price of staple crops and thus improve the welfare of consumers, but perhaps due to the modest effect on maize productivity, Ricker-Gilbert et al. (2013) observed that, on average, doubling the size of FISP reduced retail maize price by only 1.2 to 2.5%. Poverty appears not to have been significantly impacted by the program probably because of its poor targeting system. Since the inception of FISP, the national absolute poverty rate

[16] Coverage rate of a targeted, development program is the proportion of beneficiaries who are eligible for the program (poor farmers, in the case of FISP); and leakage rate is the proportion of beneficiaries who are ineligible (non-poor farmers, in the case of FISP).
[17] 57.9% and 52% were the coverage and leakage rates respectively in 2009/10 when predicted poverty was used as the measure of resource poverty. When resource poverty was defined in terms of asset ownership (or land holding) however, the coverage and leakage rates were estimated to be 50.7 (49.6%) and 56.8% (56.7%) respectively (Kilic et al., forthcoming).

decreased only marginally (only 1.3 percentage points between 2004/05 and 2010/11) while income inequality, as measured by GINI coefficient, exacerbated - increasing from 0.39 to 0.45 over the same period (Kilic et al. 2014; NSO, 2012).

## 4.3 Conceptual Framework

### 4.3.1 General Framework

The estimation of the overall gain in yield for targeting non-poor farmers instead of poor and ultra-poor farmers after accounting for the potential difference in input use efficiency and crowding out is conceptualized as follows. Let *p1* and *p0* be two groups of farmers, with farmers in group *p0* being poorer than those in group *p1*. For instance when comparing non-poor and poor households, *p1* and *p0* will denote non-poor and poor farmers respectively; but when comparing poor and ultra-poor households, *p1* represents poor farmers while *p0* represents ultra-poor farmers. Let $\Delta NUE_{p1,p0}$ be the difference in nitrogen use efficiency (NUE) – the kilograms of output obtained from the application of an additional kilogram of nitrogen – between the average farmer in group *p1* and the average farmer in group *p0*. In other words, $\Delta NUE_{p1,p0}$ represents the potential, gain in yield per kilogram of nitrogen obtained by targeting the average farmer in group *p1* instead of the average farmer in group *p0*. Targeting the average farmer in group *p1* instead of the average farmer in group *p0* will result in a potential, additional crowding out effect. Let this potential, additional crowding out effect be represented by $\Delta CO_{p1,p0}$. Because a crowding out estimate is generally an indication of the reduction in total fertilizer use resulting from access to subsidized fertilizer, $\Delta CO_{p1,p0}$ can also be interpreted as the potential, additional reduction in total fertilizer use that results from targeting the average farmer in group *p1* instead of the average farmer in group *p2*. This potential reduction in total fertilizer use ultimately leads to a potential reduction in yield. Using the notations and variables defined above, the potential reduction in yield is given by $[(\Delta CO_{p1,p0}) * NUE_{p0}]$. Based on these estimates, the overall net gain in yield for targeting the average farmer in group *p1* after accounting for the potential difference in *NUE* and crowding out between farmers in groups *p1* and *p0* is expressed as:

$$NG_{yield,p1} = \{[\Delta NUE_{p1,p0}] - [(\Delta CO_{p1,p0}) * NUE_{p0}]\} \quad (4.1)$$

With this estimate, the decision is to target FISP at farmers in group *p1* if $NG_{yield,p1}$ is (significantly) positive; otherwise, FISP should be targeted farmers in group *p0*. Sections 3.3.2 and 3.3.3 lay out the framework for measuring $\Delta NUE_{p1,p0}$ and $\Delta CO_{p1,p0}$.

### 4.3.2 Framework for Measuring $\Delta NUE_{p1,p0}$

In order to measure $\Delta NUE_{p1,p0}$, the impact of the poverty status of household on nitrogen use efficiency, the study assumes that rural agricultural households are economic agents whose goal is to obtain the highest possible yield from crop production in order to meet their food and income needs, given their available productive resources. Since maize is the main staple and the most widely cultivated crop in Malawi (cultivated by about 90% of farmers on 70% of their farm plots), the study considers only maize production. Maize yield is a function of several factors:

$$Y = f[N(P), X, H, C] \quad (4.2)$$

where $Y$ is maize yield in kilograms per hectare, $N$ is the rate of nitrogen (from inorganic fertilizer) application, $X$ is a vector of other plot-level agronomic inputs including the quantity of seeds sown, the amount of labor used on the plot, whether or not the plot is planted to a hybrid maize variety etc. $H$ is a vector of household-level variables such as adult-equivalent household size, dependency ratio etc. that are likely to affect maize production. $C$ is a vector of climatic variables including rainfall and temperature. A full list of the variables in each of the vectors are presented in table 4.1. The extent to which nitrogen application affects maize yield is hypothesized to depend on the poverty status of households, $P$. The idea is based on the premise that better-off households are better equipped to use complimentary inputs such as hired labor, pesticides, organic matter; and also have the ability to rent in plots of better soil quality, all of which boost nitrogen use efficiency. Accordingly, the poverty status of households ($P$) is modeled as nitrogen-facilitating input – an input that boost the extent to which nitrogen affects yield – in the production of maize.

### 4.3.3 Framework for Measuring $\Delta CO_{p1,p0}$

In order to measure $\Delta CO_{p1,p0}$, the potential difference in crowding out between poverty groups *p1 and p0*, following Ricker-Gilbert et al. (2011), the basic Sing, Squire and Strauss (1986) household model is used to derive the demand for commercial fertilizer for a rural agricultural household. In developing countries like Malawi where credit and labor markets are imperfect, and where households face high levels of risks because of high weather variability and other shocks, households' consumption and production decisions are likely to be non-separable. This implies that a household's desired level of input use in crop production is affected by its socio-demographic characteristics. In the presence of a large-scale farm input subsidy program like FISP, the demand for commercial fertilizer is also likely to be affected by the amount of subsidized fertilizer that a household receives. Other factors such as transaction cost, output price of agricultural goods, and the amount and quality of land available to farmers are also likely to affect households' decisions to participate in the commercial fertilizer market. It is hypothesized in this study that the extent to which the amount of subsidized fertilizer affects the demand for commercial fertilizer depends on the poverty status of households. In a setting where the demand for commercial fertilizer by a non-separable household is affected by the amount of subsidized fertilizer access, and the effect of subsidized fertilizer depends on the poverty status of households, consider the following equation:

$$F = f[S(P), P_c, P_a, T, Z, A] \quad (4.3)$$

Where $F$ and $S$ are respectively the quantity of commercial and subsidized fertilizer accessed by the household; $P$ is household poverty status; $P_c$ and $P_a$ are prices of commercial fertilizer and the agricultural good produced respectively; $T$ represents a vector of factors such as distance to road and urban centers that determine the fixed transfer costs associated with the use of commercial fertilizer; $Z$ is a vector of household characteristics; and fixed quantity of land is represented by $A$.

## 4.4 Empirical Model for Estimating $\Delta NUE_{p1,p0}$

The effect of household poverty status on nitrogen use efficiency, $\Delta NUE_{p1,p0}$, is estimated by specifying the yield function in equation (4.2) with a two-level multilevel model. A household fixed effects model has also been considered to check the robustness of the estimates. A multilevel model is used because it allows for the explicit expression of nitrogen use efficiency as a function of household poverty status; and such an expression is of particular interest in this study. In addition to this, the use of multilevel model has two other advantages. First, it accounts for the hierarchical structure in the dataset – plots are nested within households – by modeling the variations at all levels of the hierarchy (plot and household levels) and by accounting for the intra-household correlation that is likely to result from the fact that plots belonging to the same household share the same management and related conditions. The existence of such a hierarchy in the data has implications for statistical validity and should therefore not be ignored (Goldstein, 1995; Elhorst, 2014; Carrado and Fingleton, 2011). Second, the multilevel model distinguishes (explicitly) between plot-level and household-level covariates in the model by allowing for the coefficients of the plot-level variables to vary within households. This is particularly important in this study because of the interest in understanding the how nitrogen use efficiency vary across poor and non-poor households. For yield on plot $i$, belonging to household $h$, the model at the various level of the hierarchy is specified as:

<u>Plot-level model</u>

$$Y_{ih} = \beta_{0h} + \beta_{1h} N_{ih} + X_{ih}\beta_x + \varepsilon_{ih} \tag{4.4}$$

where $Y_{ih}$ is yield; $N_{ih}$ is nutrient application rate; $X_{ih}$ is a vector of other plot-level variables affecting maize yield; and $\varepsilon_{ih}$ represents the plot-level error term. $\beta_{0h}$ is the random intercept, varying across households, but has the same value for individual plots belonging to household $h$. $\beta_{0h}$ therefore measures the mean yield for plots in household

$h$. $\beta_{1h}$ is the random slope for the nitrogen variable which varies across households. $\beta_x$ is a vector of fixed coefficients for the other plot-level variables, where the subscript *x* represents the corresponding plot-level variable in vector $X_{ih}$. Unlike the nitrogen use efficiency ($\beta_{1h}$), these coefficients are fixed because their variation across households is not of any particular interest in this study.

<u>Household-level model</u>

The study hypothesizes that variability in the nitrogen use efficiency ($\beta_{1h}$) depends on the poverty status of households ($P_h$); and the variability in the random intercept ($\beta_{0h}$) is explained by other household level variables ($H_h$). Thus, in the household-level model, equations (4.5a) and (4.5b), the nitrogen use efficiency and the random intercept are expressed as:

$$\beta_{1h} = \beta_{10} + \beta_{1p}P_h + U_{1h} \tag{4.5a}$$

$$\beta_{0h} = \beta_{00} + H_h\alpha_{0m} + U_{0h} \tag{4.5b}$$

where $\beta_{1p}$ is the effect of household poverty status on nitrogen use efficiency i.e. $\Delta NUE_{p1,p0}$. $\beta_{00}$ and $\beta_{10}$ are the household-level group effect for the intercept and nitrogen use efficiency (i.e. the mean yield and nitrogen use efficiency) respectively; and household-specific variation around these values are represented by $U_{0h}$ and $U_{1h}$ respectively. $\alpha_{0m}$ represents the contribution of the other household variables to the variation in the random intercept, where the subscript *m* represent the corresponding household-level variable in the vector $H_h$.

Full model

Substitution of equations (4.5a) and (4.5b) into equation (4.4) results in the full hierarchical model which is given by:

$$Y_{ih} = \beta_{00} + \beta_{10}N_{ih} + \beta_{1p}(P_h * N_{ih}) + X_{ih}\beta_x + H_h\alpha_{0m} + (U_{0h} + U_{1h}N_{ih} + \varepsilon_{ih}) \quad (4.6)$$

$\beta_{1p}$ represents $\Delta NUE_{p1,p0}$; and the terms in bracket, $(U_{0h} + U_{1h}N_{ih} + \varepsilon_{ih})$, represent the total error term in the full model — $\varepsilon_{ih}$ from the plot level, and $U_{0h}$ *and* $U_{1h}N_{ph}$ from the household level.

## 4.5 Empirical Model for Estimating $\Delta CO_{p1,p0}$

In order to estimate $\Delta CO_{p1,p0}$, the difference in the crowding out of commercial fertilizer by subsidized fertilizer across poverty groups, the conceptual model in equation (4.3) and the error term are specified as follows:

$$C_{it} = \gamma S_{it} + X_{it}\beta + \varepsilon_{it} \quad (4.7a)$$

$$\varepsilon_{it} = a_i + \mu_{it} \quad (4.7b)$$

where $C$ and $S$ are quantities of commercial and subsidized fertilizers acquired by household $i$ in time *t*. $\gamma$ represents the parameter that captures the extent to which subsidized fertilizer crowds out commercial fertilizer. $X_{it}$ is a vector of other variables that affect the demand for commercial fertilizer; and $\beta$ is a vector of the corresponding parameters. $X_{it}$ consists of such variables as price of commercial fertilizer at the time of planting, real price of maize in the past lean season, distance to the nearest road, a soil quality index, average rainfall in the past year and household socio-demographic characteristics listed in table 4.1. The error term, $\varepsilon_{it}$, is made up of two components: unobserved time-invariant factors ($a_i$) and unobserved time-varying factors which affect the demand for commercial fertilizer. The unobserved time factors consist of such factors as the management ability of farmers; and the unobserved time-varying factors consists of factors such as health shocks and political turmoil.

$\Delta CO_{p0,p1}$ can be estimated using two approaches. The first approach involves interacting the subsidized fertilizer variable with the variable measuring the poverty status in equation (4.7a), and finding out whether the coefficient on the interaction term is significantly different from zero. The second approach involves estimating equation (4.7a) without the interaction term, generating the partial effect of the subsidized fertilizer for each household, and then using a simple t-test to test whether the partial effect varies significantly across poverty groups. The second approach is adopted in this study because, as the next section discusses, the subsidized fertilizer variable is potentially endogenous, implying the first approach would require multiple instrumental variables which are not easy to come by.

### 4.5.1 Potential Endogeneity of Subsidized Fertilizer in a Demand for Commercial Fertilizer Model

As described in section 4.2, coupons to be redeemed for subsidized inputs are not distributed randomly to beneficiaries; hence unobservable factors that affect farmer's participation in the commercial fertilizer market such as political turmoil, weather and health shocks could influence the amount of subsidized inputs that a household receives. As such, the quantity of subsidized inputs that a household receives is likely to be endogenous in a commercial fertilizer equation. This implies that, in terms of the empirical models, $S_{it}$ could be potentially correlated with $a_i$ and/or $\mu_{it}$. Failure to control for such correlations could potentially result in inconsistent estimates of crowding out.

This study uses the Mundlak-Chamberlin device to account for the potential correlation between $S_{it}$ and $a_i$, and the control function approach (CF) to account for the correlation between $S_{it}$ and $\mu_{it}$ (Mundlak, 1978; Chamberalain, 1984). The Mundlak-Chamberlin device is used instead of household fixed effects because many farmers in Malawi do not use fertilizer in crop production, so the data take on properties of non-linear corner solutions. The implementation of the Mundlak-Chamberlin device involves the inclusion of a vector of variables consisting of the household-level means of time-varying covariates. The CF approach in this case involves estimating a reduced form model of quantity of subsidized fertilizer acquired and including the residuals from this model as an additional explanatory variables in the commercial fertilizer model. The significance or otherwise of the coefficient on this additional explanatory variable tests and corrects for the potential correlation between $S_{it}$ and $\mu_{it}$.

The CF approach requires an instrumental variable in the reduced form model of subsidized fertilizer. The instrumental variable should strongly correlate with $S_{it}$ but be uncorrelated with $\mu_{it}$ in the commercial fertilizer model when the other covariates are controlled for. Following Ricker-Gilbert et al. (2011), the number of years that the household head has been living in the community is used as the instrumental variable. This variable is used because it represents a “sociopolitical capital” that could affect the quantity of subsidized fertilizer received by a household (Ricker-Gilbert et al., 2011).

Also, after conditioning on other covariates, it is not likely that the number of years that the household head lived in a village would correlate with unobserved time-varying factors in the commercial fertilizer model.

The reduced form model in the CF approach is specified as a Tobit model. A Tobit model is used because the subsidized fertilizer variable is a corner solution outcome – there are many zeros in the subsidized fertilizer variable due to the fact that only about 50% of households receive subsidized fertilizer each year. The commercial fertilizer demand variable is also a corner response outcome but instead of a Tobit model, the demand model for commercial fertilizer is specified with a double-hurdle model proposed by Cragg (1971)[18]. The DH model is used in order to account for the possibility that factors affecting the farmer's decision to participate in the fertilizer market may be different from those that affect the quantity purchased of commercial fertilizer once the decision to participate has been made.  The double-hurdle model also allows the same factors to affect the decision to participate in the market and the quantity purchased differently. The decision to participate in the commercial fertilizer market is modeled in hurdle 1 while the quantity purchased of fertilizer is modeled in hurdle 2 once the decision to participate has been made.

The unconditional PE of the subsidized fertilizer coefficient are derived from the DH model for each household in the sample. A simple student t-test is subsequently used to determine whether there is a significant difference in PE across poverty groups.

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[18] The Tobit model is nested within the double hurdle because unlike the double hurdle model, it requires that the decision to participate in the commercial fertilizer market and the amount purchased are determined by the same process. The choice between the two models is usually based on a Likelihood Ratio (LR) test.

## 4.6 Data and Sample Selection

The study uses the two-wave Malawi Integrated Household Panel Survey (IHPS) data collected by the collected by the National Statistical Office of Malawi (NSO) with support from the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) program. The survey for the first wave of the dataset covered 3247 households (hereafter baseline households) in the 2009/2010 agricultural year. The sampling was representative at the national, regional and urban/rural levels. The survey for the second wave of the dataset was conducted in the 2012/2013 agricultural year and attempted to track and resample all the baseline households as well as individuals (projected to be at least 12 years) that split-off from the baseline households between 2010 and 2013 as long as they were neither guests nor servants and are still living in mainland Malawi. Once a split-off individual was located, the new household that he/she formed or joined was also brought into the second wave. In all, a total of 4000 households were traced back to 3104 baseline households. An overwhelming majority, 76.80%, of the 3104 baseline households did not split over time; 18.49% split into two households; and rest (4.70%) split into 3-6 households. Considering the 20 baseline household that died in their entirety between 2010 and 2013 and the fact that 4,000 households could be traced back to 3,104 baseline households, the dataset has an overall household attrition rate of only 3.78%.

The study dropped all non-agricultural households (580 and 845 households in the first and second waves respectively), as well as urban agricultural households (370 and 438 households in the first and second waves respectively). The urban agricultural households were dropped because farming in Malawi is predominantly rural. In order to avoid reverse causality in the maize production function, all the households for which questions about their food and non-food consumption were asked after the harvesting of agricultural products were also dropped. In the end, a panel of 1,667 households (2472 maize plots), 771 households (1,127 maize plots) in the first wave and 896 household (1,347) was used for the analyses.

Attrition bias in the data could not be tested because there are no regression-based tests for attrition when fixed effects or MC devise models are used with a panel of only two wave. A panel of more than two-waves are required for such tests (Wooldridge, 2010; Mason and Smale, 2013). That notwithstanding, the study is confident that attrition bias is not likely to be a concern because as indicated earlier, the attrition rate is only 3.78% at the household level.

## 4.7 Classification of Households into Poverty Groups

Households are classified into poverty groups using consumption expenditure and an asset-based wealth index[19]. Both consumption expenditure and the assert-based wealth index serve as proxies for the long-term economic status of households. The theoretical underpinning of using both variables as measures of long-term economic status of households has been established in the literature (Deaton and Muellbauer, 1980; Deaton 1997; Deaton and Zaidi, 1999; Filmer and Pritchett, 2001). Both measures are used for the classification of households into poverty groups in order to consider all the possible

[19] Consumption expenditure and asset-based wealth index are chosen over income for the poverty classification because both variables reflect smoothing and are easier to measure than income in rural settings.

empirically proven ways (expenditure and asset ownership) by which the poverty status of households may be expressed.

The consumption expenditure variable represents aggregate annual expenditure on food and non-food products. The food expenditure component was constructed by adding up expenditure on all food items consumed by the household at home and away from home over the past seven days. The non-food expenditure component consists of expenditure on utilities such as kerosene and electricity, health, transport, communications, recreation, education, furnishing, personal care, durable assets and housing. A more elaborate description of the construction of the consumption expenditure variable can be found in Chapter two (section 2.5.1) of this dissertation and in World Bank (2013). Using the official poverty and ultra-poverty lines of MKW 85852 and MKW 53262 respectively, households are classified into non-poor, poor and ultra-poor. Household were also classified into quintiles of consumption expenditure.

Following Filmer and Pritchett (2001), the asset-based wealth index is measured as a linear index generated from indicators of household asset ownership and housing condition using principal-components analysis (PCA) to derive weights. PCA is a statistical technique used to extract from a group of variables a few orthogonal linear combinations of the variables that capture the common information most successfully. The first principal component of the asset and housing condition indicators is the linear index that captures the largest amount of information, so this study uses that as the measure of wealth. Filmer and Pritchett (2001) demonstrates the construction and internal validity of this index as a measure of wealth.

The assets included in the construction of the index include ownership of mortar, bed, table, chair, fan, air conditioner, radio, CD or cassette player, television, sewing machine, stove, refrigerator, washer, bicycle, motorbike or vehicle, drum, sofa, coffee table, cupboard, lantern, desk, clock, iron, computer, satellite dish, solar, generator and cellphone. The housing condition included in the construction of the index include the material (permanent or not) of which the dwelling, outer walls, roof and floor are made of; the source of lighting (electricity or otherwise) in the house; the source of water (pipe or otherwise); the kind of toilet facility (water closet or otherwise); number of rooms in the house; and number of rooms per capita. Following Filmer and Pritchett (2001) and Dzanku (2015) households within the top 60% of the distribution of the wealth index are classified as non-poor, and those within the bottom 40% are classified as poor. Using the same logic, households with the bottom 16% are classified as ultra-poor. As in the case of consumption expenditure, households were also classified into quintiles of the wealth index.

## 4.8 Results

### 4.8.1 Descriptive Statistics

The descriptive statistics of the key variables used in the study are presented in tables 4.1 and 4.2. Table 4.1 presents the descriptive statistics for the pool sample and for the 2010 and 2013 sub-samples while table 4.2 compares the descriptive statistics across poor and non-poor farmers in both 2010 and 2013 survey years. The average maize yield was 1272 kg/ha in 2010 but increased significantly to 1574 kg/ha in 2013. The nitrogen application rate (47.58 kg/ha in 2010) and the proportion of plots planted to hybrid maize seeds (39.70%) did not change significantly over time. Hence the increase in maize yield is likely not attributable to increased use of modern inputs, but probably attributable to the 35% increase in the proportion of plots on which organic fertilizer was applied, the 25% increase in labor utilization, and the 18% increase in seed application rate. The increase in yield could also be due to farmers becoming more experienced in the use of inputs to in maize production.

Using the asset poverty classification, the estimates shows that, in 2010, 58.30% of farmers were non-poor, 20.40% were poor and 21.30% were ultra-poor; and this proportions did not change significantly between 2010 and 2013. Across poverty groups, the estimates indicate that maize yield of non-poor households is significantly greater than that of poor farmers in both years. In 2013 for instance, maize yield for asset non-poor farmers (1804.31 kg/ha) was about 44% higher than that of non-poor farmers. The difference in yield between the non-poor and poor farmers can be attributed to non-poor farmers using significantly more inorganic fertilizer and having a higher level of compliance with fertilizer (both nitrogen and total fertilizer) recommendations than poor farmers.

The average quantity of subsidized fertilizer acquired by households was on average 41.76kg in 2010 and increased slightly (not significantly) to 44.62kg in 2013. The quantity of commercial fertilizer however increased significantly from 143.79kg in 2010 to 184.70kg in 2013. Table 4.2 shows that, non-poor farmers acquired significantly more subsidized and commercial fertilizer than poor farmers. This estimate corroborates previous studies on access to subsidized inputs which reported that non-poor farmers are more likely to access, and acquire higher quantities of, subsidized inputs than poor farmers (Chibwana et al, 2012;  Ricker-Gilbert et al., 2011). In 2013 for instance, non-poor farmers acquired 25% and 90% more subsidized and commercial fertilizer respectively than poor formers. The fact that non-poor farmers acquired significantly more commercial fertilizer than poor farmers provides an indication that crowding out of commercial fertilizer by subsidized fertilizer is likely to be higher among non-poor farmers than it would be among poor farmers.

### 4.8.2 Effect of Poverty Status on Nitrogen Use Efficiency ($\Delta NUE_{p1,p0}$)

Results of the multilevel model of the effect of the poverty status of farmers on nitrogen use efficiency (NUE) are presented in tables 4.3 and 4.4, and in tables 4.A1 and 4.A2 in appendix B[20]. A likelihood ratio test shows that the multilevel model chosen for this analysis fits the data better than a linear model. The estimates indicate that, as expected, nitrogen application has a positive and significant effect on maize yield. In general, non-poor farmers have significantly higher NUE than poor and ultra-poor farmers irrespective of how poverty is measured (consumption expenditure or asset ownership). Using the two-category (poor/non-poor) consumption poverty classification, the estimates indicate that NUE for poor farmers is 3.38 kg lower than that of their non-poor counterparts (table 4.3, column 2); and using the three-category (ultra-poor/poor/non-poor) consumption poverty classification, the NUE for ultra-poor and poor farmers is 4.47kg and 3.02kg respectively lower that the NUE of non-poor farmers (table

[20] For robustness check, results of the household fixed effects model are also presented in table 4.A3. Results from this model are quite similar to the results of the multilevel model.

4.3, column 3). In terms of consumption quintiles, the estimates indicate that the NUE for farmers in the fifth quintile is 4.32 kg and 3.59 kg lower the NUE of farmers in the first and second quintiles respectively; but the NUE of farmers in the third and fourth quintiles are however not significantly different from that of farmers in the fifth quintile (table 4.3, column 4). The difference in NUE across asset poverty groups follow a similar pattern. Based on the two-category asset poverty classification, the NUE of poor farmers is 4.93kg lower than the NUE of non-poor farmers; and based on the three-category asset poverty, NUE of ultra-poor and poor farmers is 6.84 kg and 3.51 kg respectively lower than that of non-poor farmers (table 4.4, columns 2 and 3). In terms of asset quintiles, the estimates indicate that the NUE of farmers in the fifth quintile is significantly greater than the NUE of the lower quintiles (table 4.4, columns 4).

The fact that non-poor farmers are remarkably more productive (have higher NUE) than poor and ultra-poor farmers suggests that the food security objective of FISP would be better served by targeting non-poor farmers; but the potential difference in crowding out across poverty groups ought to be considered before this suggestion can be made. The following section addresses the potential difference in crowding out across poverty groups.

### 4.8.3 Crowding Out of Commercial Fertilizer by Subsidized Fertilizer

#### 4.8.3.1 The Average Crowding Out Estimate

Table 4.6 presents the double hurdle model of the factors that influence demand for commercial fertilizer. The coefficients in hurdle 1 of the table are conditional Average Partial Effects (APEs) obtained using the *margins* command in Stata. In order to account for the first-stage reduced form estimation of access to subsidized fertilizer, the corresponding p-values are obtained using bootstrapping with 250 repetitions. The residuals from the reduced form equation of access to subsidized fertilizer is significant at the 1% level in hurdle 1, indicating that subsidized fertilizer is endogenous in the participation model of commercial fertilizer. The coefficient on the subsidized fertilizer variable in hurdle 1 is negative and significant, indicating that the quantity of subsidized fertilizer that a household received reduces the household's probability of participating in the commercial fertilizer market. The p-value of the residuals in hurdle 2 is 0.90, suggesting that subsidized fertilizer is not endogenous in the commercial fertilizer model once the decision to purchase has been made. Hence the residual is dropped from hurdle 2. The APEs and the p-values in hurdle 2 are obtained using the *margins* command in Stata.

The estimates in hurdle 2 indicate that once the decision to purchase fertilizer in the commercial market has been made, a kilogram of subsidized fertilizer reduces the quantity demanded of commercial fertilizer by 0.5kg, all things being equal. This estimate indicates that subsidized fertilizer crowds out commercial fertilizer, corroborating the findings of previous studies on crowding out (Ricker-Gilbert et al., 2011). Using the partial effects and likelihood functions of hurdles 1 and 2, the unconditional APE of subsidized fertilizer is estimated to be -0.86. The -0.86 APE is the overall crowding out effect, implying that each kilogram of subsidized fertilizer that a household acquires reduces the household's demand of commercial fertilizer by -0.86 kg, all things being equal. The -0.86 kg crowding out estimate obtained in this study is higher than the -0.22 kg estimated by Ricker-Gilbert et al. (2011). Because this study followed the same methodological approach as Ricker-Gilbert et al. (2011), the higher crowding out estimate found in this study suggests that crowding out has increased substantially over time. The increase in crowding out could have resulted from an increase in demand for commercial fertilizer.

4.8.3.2 Effect of Poverty Status on Crowding Out, $\Delta CO_{np,p}$

Table 4.7 presents estimates of crowding out (unconditional APEs) across the various poverty groups; and the difference in the crowding-out estimates across the various poverty groups are presented in table 4.8. Generally, the crowding out estimates for non-poor households is significantly higher than it is for poor and ultra-poor households. This is expected because non-poor farmers, as the descriptive statistics indicated, purchase significantly larger quantities of commercial fertilizer than poor households. Using the two-category consumption poverty classification, the estimates indicate that crowding out is 0.045 kg (5.4%) higher among non-poor households than it is among poor households; and using the three-category consumption poverty classification, crowding out among non-poor household is 0.034 kg (4.5%) and 0.069 kg (8.6%) greater than the estimates among poor and ultra-poor households respectively. The estimates also show that crowding out among poor households is 0.035 kg (4.3%) greater than ultra-poor households. The variation in crowding out across asset poverty groups follows in a similar but more pronounced pattern. Based on the two-category asset poverty classification, crowding out is 0.130 kg (16.6%) higher for non-poor households than it is for poor households. In terms of the three-category asset poverty classification, crowding out among non-poor households is 0.095 kg (11.6%) and 0.163 kg (21.8%) greater than the estimate among poor and ultra-poor households.

The above results suggest that targeting poor farmers would reduce crowding out, and consequently increase total fertilizer use.

### 4.8.4 Overall Net Gain in Yield for Targeting the Average Non-poor Farmer ($NG_{yield,p1}$)

This section presents the results of the overall net gain in yield for targeting the average non-poor farmer after accounting for the potential difference in NUE and crowding out between non-poor and poor households. It is clear from the variation of NUE and crowding out across poverty groups and their implication for targeting that there is a trade-off between targeting productive farmers (non-poor farmers, as the NUE estimates indicate) and targeting to reduce crowding out (poor farmers, as the crowding out estimates indicate). Targeting productive farmers will help serve the food security objective better but results in significantly higher levels of crowding out; while targeting to reduce crowding out in order to ensure higher overall fertilizer use results in lower levels of NUE and hence lower crop output. This study further examines the trade-off by estimating the overall net gain in yield when FISP is targeted at the average non-poor farmer after accounting for the differences in NUE and crowding out across the poor and non-poor farmers. The estimates required for this exercise and the results of the exercise are presented in tables 4.9 and 4.10 respectively. The estimates indicate that between any poverty groups, the overall net gain for targeting the better off farmers is positive and significant. For instance, using the two-category poverty classification, the overall net gain in yield for targeting consumption non-poor and asset non-poor farmers instead of their poor counterparts is 3.136kg and 4.330kg per kilogram of nitrogen respectively, after accounting for the difference in NUE and crowding out between poor and non-poor farmers. Using the three-category poverty classification, the overall gain in yield for targeting consumption non-poor and asset non-poor farmers instead of their ultra-poor counter parts is 4.170kg and 6.404kg respectively. Comparing poor to ultra-poor farmers, the estimates further show that the overall net gain in yield for targeting poor farmers instead of ultra-poor farmers is also positive and significant. This implies that although a significantly higher crowding out would be incurred when FISP is targeted at non-poor farmers, the productivity gain in targeting such farmers outweighs the additional crowding out effect. Thus, overall, the food security goal of FISP would be better served if the program were targeted at non-poor farmers.

## 4.9 Conclusions and Policy Recommendations

Targeted farm input subsidy programs have become major development policies in many Sub-Sahara African (SSA) countries. Like other targeted development programs, the success of TFISPs depends integrally on the effectiveness of the targeting process used in identifying and reaching beneficiaries. Targeting plays a crucial role in that it determines the beneficiaries of the program, the amount of inputs they receive, and hence how the inputs are used. The eventual impacts of the program are therefore closely linked to the quality of the targeting process. That notwithstanding, the weight of the empirical evidence suggests that targeting of most TFISPs in SSA has not been effective. The goal of this study has been to provide guidance for determining the category of farmers that should be targeted in order to maximize the benefits of TFISPs using a two-year panel data from Malawi. Specifically, the study estimated the overall gain in productivity for targeting non-poor farmers instead of poor and ultra-poor farmers after accounting for differences in input use efficiency and crowding out across poverty groups. The study also investigated how nitrogen use efficiency and crowding out of commercial fertilizer by subsidized fertilizer vary between poor and non-poor farmers. Farmers were classified into poverty groups – non-poor, poor and ultra-poor – using consumption expenditure and a wealth index computed from household asset ownership. The consumption expenditure and the wealth index used in the poverty classification can computed using information that can easily be collected from households.

The results indicate that non-poor farmers are significantly more productive than poor and ultra-poor farmers irrespective of whether poverty is measured by consumption expenditure or by the asset-based wealth index. The study also found that crowding out of commercial fertilizer by subsidized fertilizer is significantly higher among non-poor farmers than it is among poor and ultra-poor farmers. After accounting for these differences in productivity and crowding out across poverty groups, the study found that, on average, the overall net gain in yield for targeting consumption non-poor and asset non-poor farmers instead of their poor counterparts is 3.136kg and 4.330kg per kilogram of nitrogen. Comparing non-poor to ultra-poor farmers, the overall gain in yield for targeting consumption poor non-poor and asset non-poor farmers instead of their ultra-poor counterparts is 4.12kg and 6.40kg per kilogram of nitrogen.

These results have two key implications for the targeting of FISP and other TFISPs in SSA. First, since poor farmers are significantly less productive than non-poor farmers after accounting for crowding out, the two goals of FISP – promoting household and national food security by increasing food production, and reducing poverty by increasing household income – can hardly be achieved together by targeting poor farmers. The study therefore recommends that FISP and other TFISPs be focused on a single objective. Second, the results reveal that there is a trade-off between targeting for increased productivity and targeting to reduce crowding out. Further analysis of the trade-off suggests that the overall net gain in yield for targeting the average non-poor farmer instead of the average poor farmer is positive and significant. Hence the study also recommends that FISP and other TFISPs should be targeted at non-poor farmers if the goal is to promote household and national food security.

## 4.10 List of References


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Table 4-1 Descriptive Statistics by Survey Year

| | Pooled | | Year = 2010 | | Year = 2013 | |
|---|---|---|---|---|---|---|
| | Mean | Stan dev. | Mean | Stan dev. | Mean | Stan dev. |
| Maize yield (Kg/ha) | 1,437.46 | 1,077.30 | 1,272.17 | 936.82 | 1,573.89*** | 1,169.14 |
| Nitrogen application rate (Kg/ha) | 46.35 | 45.79 | 47.58 | 45.00 | 45.34 | 46.42 |
| Non-poor (consumption) | 63.80 | 0.48 | 63.20 | 0.48 | 64.30 | 0.48 |
| Poor (consumption) | 25.20 | 0.43 | 24.90 | 0.43 | 25.40 | 0.43 |
| Ultra-poor (consumption) | 11.00 | 0.32 | 11.90 | 0.33 | 10.30 | 0.31 |
| Non-poor (asset) | 58.30 | 0.49 | 58.30 | 0.49 | 58.20 | 0.49 |
| Poor (asset) | 20.00 | 0.40 | 20.40 | 0.40 | 19.70 | 0.40 |
| Ultra-poor (asset) | 21.70 | 0.40 | 21.30 | 0.40 | 22.10 | 0.40 |
| Below recommended N application rate (1/0) | 78.50 | 0.42 | 78.40 | 0.42 | 78.60 | 0.41 |
| Above recommended N application rate (1/0) | 14.90 | 0.36 | 15.20 | 0.37 | 14.50 | 0.35 |
| Applied basal fertilizer on time (1/0) | 29.70 | 0.46 | 36.50 | 0.49 | 24.10*** | 0.44 |
| Fertilizer used is basal fertilizer | 50.20 | 0.50 | 47.40 | 0.50 | 52.40** | 0.50 |
| Applied organic fertilizer (1/0) | 16.00 | 0.36 | 13.40 | 0.33 | 18.10** | 0.38 |
| Seed rate (Kg/ha) | 25.72 | 21.81 | 22.99 | 25.42 | 27.96*** | 17.95 |
| Used hybrid seed (1/0) | 37.70 | 0.49 | 39.70 | 0.49 | 36.00 | 0.48 |
| Pure stand (1/0) | 48.10 | 0.50 | 53.50 | 0.50 | 43.60*** | 0.50 |
| Plot size (ha) | 0.42 | 0.26 | 0.43 | 0.25 | 0.40** | 0.27 |
| Labor (days) | 132.74 | 94.55 | 116.92 | 80.07 | 145.80*** | 103.88 |
| Soil is of good quality (1/0) | 45.80 | 0.50 | 44.70 | 0.50 | 46.60 | 0.50 |
| Soil is of fair quality (1/0) | 41.30 | 0.49 | 41.70 | 0.49 | 40.90 | 0.50 |
| Plot is sloppy (1/0) | 46.70 | 0.50 | 47.00 | 0.50 | 46.30 | 0.50 |
| Plot is swampy (1/0) | 15.80 | 0.36 | 16.40 | 0.37 | 15.30 | 0.36 |
| Soil is sandy clay (1/0) | 53.80 | 0.50 | 52.50 | 0.50 | 54.80 | 0.50 |
| Plot show signs of erosion (1/0) | 39.00 | 0.49 | 40.20 | 0.49 | 38.10 | 0.48 |
| Female plot manager (1/0) | 30.40 | 0.45 | 27.20 | 0.44 | 33.00** | 0.46 |
| Age of plot manager (years) | 41.78 | 15.39 | 40.96 | 15.23 | 42.45* | 15.49 |
| Years of education of plot manager | 4.85 | 3.86 | 4.88 | 3.84 | 4.82 | 3.88 |
| African Adult Male Equivalent | 3.87 | 1.63 | 3.79 | 1.58 | 3.94** | 1.67 |
| Dependency ratio (%) | 121.53 | 95.66 | 124.36 | 98.01 | 119.19 | 93.63 |
| Distance to boma (Km) | 38.85 | 27.49 | 52.61 | 27.92 | 27.49*** | 21.48 |
| Avg. 12-month total rainfall(mm) for July-June | 825.56 | 80.86 | 828.55 | 87.84 | 823.10** | 74.31 |
| Annual Mean Temperature (°C * 10) | 215.78 | 17.76 | 216.53 | 18.14 | 215.17 | 17.42 |
| Quantity of subsidized fertilizer acquired (Kg) | 43.29 | 41.51 | 41.76 | 41.12 | 44.62 | 41.84 |
| Quantity of commercial fertilizer acquired (Kg) | 164.92 | 228.93 | 143.79 | 203.91 | 184.70*** | 248.20 |

***, **, * imply significantly different between 2010 and 2013

Table 4-2 Descriptive Statistics by Survey Year by Poverty Status

| | 2010 | | 2013 | |
|---|---|---|---|---|
| | Non-poor | Poor | Non-poor | Poor |
| Maize yield (Kg/ha) | 1,432.90*** | 1,047.21 | 1,804.31*** | 1,253.14 |
| Nitrogen application rate (Kg/ha) | 55.39*** | 36.66 | 55.83*** | 30.73 |
| Below recommended N application rate (1/0) | 72.95*** | 86.00 | 72.39*** | 87.35 |
| Above recommended N application rate (1/0) | 20.25*** | 8.23 | 19.62*** | 7.45 |
| Applied basal fertilizer on time (1/0) | 37.9 | 34.44 | 24.72 | 23.30 |
| Applied inorganic fertilizer twice (1/0) | 81.99*** | 70.86 | 80.25*** | 58.67 |
| Fertilizer used is basal fertilizer | 55.79*** | 35.62 | 62.01*** | 39.14 |
| Applied organic fertilizer (1/0) | 14.65 | 11.69 | 19.36 | 16.32 |
| Seed rate (Kg/ha) | 21.40* | 25.22 | 27.76 | 28.24 |
| Used hybrid seed (1/0) | 44.23*** | 33.41 | 37.84 | 33.33 |
| Pure stand (1/0) | 54.92 | 51.52 | 44.74 | 41.94 |
| Plot size (ha) | 46.28*** | 39.36 | 43.65*** | 35.74 |
| Labor (days) | 111.20** | 124.93 | 144.24 | 147.98 |
| Soil is of good quality (1/0) | 50.32*** | 36.88 | 46.79 | 46.42 |
| Soil is of fair quality (1/0) | 39.18 | 45.33 | 42.07 | 39.33 |
| Plot is sloped (1/0) | 45.65 | 49.00 | 47.80 | 44.33 |
| Plot is swampy (1/0) | 17.31 | 15.24 | 16.06 | 14.25 |
| Soil is sandy clay (1/0) | 53.04 | 51.67 | 55.56 | 53.83 |
| Plot show signs of erosion (1/0) | 39.98 | 40.47 | 36.73 | 39.89 |
| Female plot manager (1/0) | 24.81 | 30.44 | 29.65** | 37.70 |
| Age of plot manager (years) | 42.22*** | 39.19 | 44.79*** | 39.19 |
| Years of education of plot manager | 5.79*** | 3.62 | 5.60*** | 3.74 |
| African Adult Male Equivalent | 3.964*** | 3.53 | 4.09*** | 3.73 |
| Dependency ratio (%) | 117.03** | 134.60 | 110.32*** | 131.55 |
| Distance to boma (Km) | 53.83 | 50.91 | 27.90 | 26.92 |
| Avg 12-month total rainfall(mm) for July-June | 833.08*** | 822.22 | 824.13 | 821.67 |
| Annual Mean Temperature (°C * 10) | 217.01 | 215.84 | 214.46 | 216.16 |
| Quantity of subsidized fertilizer acquired (Kg) | 47.07*** | 34.41 | 48.97*** | 38.88 |
| Quantity of commercial fertilizer acquired (Kg) | 180.81*** | 87.94 | 220.89*** | 116.49 |

***, **, * imply significant difference between non-poor and poor farmer

Table 4-3 Impact of (consumption) Poverty on Nitrogen Use Efficiency

(Dependent variable = maize yield (kg/ha))

| VARIABLES | Non-poor vs poor | Non-poor vs poor vs ultra-poor | Consumption quintiles |
|---|---|---|---|
| Nitrogen application rate (Kg/ha) | 8.718*** | 8.739*** | 9.653*** |
| | (1.450)[a] | (1.450) | (1.627) |
| Nitrogen application rate squared | 0.006 | 0.006 | 0.003 |
| | (0.011) | (0.011) | (0.011) |
| Poor * nitrogen application rate | -3.376*** | -3.019*** | -- |
| | (0.922) | (1.013) | |
| Ultra-poor * nitrogen application rate | -- | -4.465*** | -- |
| | | (1.351) | |
| First quintile * nitrogen application rate | -- | -- | -4.321*** |
| | | | (1.381) |
| Second quintile * nitrogen application rate | -- | -- | -3.590*** |
| | | | (1.338) |
| Third quintile * nitrogen application rate | -- | -- | -0.725 |
| | | | (1.370) |
| Fourth quintile * nitrogen application rate | -- | -- | -1.212 |
| | | | (1.208) |
| Below recommended nitrogen application rate (1/0) | 96.495 | 91.500 | 94.233 |
| | (106.668) | (107.305) | (106.842) |
| Above recommended nitrogen application rate (1/0) | -204.521 | -202.685 | -196.010 |
| | (124.744) | (124.431) | (124.068) |
| Applied basal fertilizer on time (1/0) | 158.702*** | 159.430*** | 155.490*** |
| | (57.534) | (57.476) | (57.731) |
| Applied organic fertilizer (1/0) | 223.656*** | 223.318*** | 222.701*** |
| | (62.183) | (62.242) | (62.721) |
| Seed rate (Kg/ha) | 3.716*** | 3.737*** | 3.727*** |
| | (1.080) | (1.081) | (1.081) |
| Used hybrid seed (1/0) | 71.598 | 71.286 | 73.391 |
| | (44.931) | (44.918) | (44.711) |
| Pure stand (1/0) | -128.015*** | -129.637*** | -127.311*** |
| | (43.270) | (43.270) | (43.416) |
| Plot size (ha) | -1,121.032*** | -1,117.205*** | -1,115.696*** |
| | (267.271) | (267.280) | (267.941) |
| Plot size squared | 504.382*** | 500.586*** | 496.523** |
| | (192.800) | (192.381) | (193.110) |
| Labor (days) | 1.088*** | 1.079*** | 1.088*** |
| | (0.297) | (0.298) | (0.297) |
| Soil is of good quality (1/0) | 199.826*** | 198.950*** | 202.057*** |
| | (59.526) | (59.630) | (59.687) |
| Soil is of fair quality (1/0) | 173.052*** | 172.211*** | 173.044*** |
| | (56.097) | (56.224) | (56.404) |
| Plot is sloppy (1/0) | -31.560 | -32.681 | -31.084 |
| | (43.348) | (43.396) | (43.488) |
| Plot is swampy (1/0) | -62.787 | -62.827 | -65.357 |
| | (61.095) | (61.061) | (60.789) |
| Soil is sandy clay (1/0) | 53.839 | 55.267 | 54.359 |
| | (44.481) | (44.512) | (44.690) |
| Plot show signs of erosion (1/0) | 25.718 | 24.967 | 26.643 |
| | (53.417) | (53.486) | (53.462) |
| Female plot manager (1/0) | -121.001** | -120.232** | -115.662** |
| | (51.803) | (51.837) | (51.684) |
| Age of plot manager (years) | 0.152 | 0.134 | 0.028 |
| | (1.666) | (1.667) | (1.667) |

[a] Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4.3: Cont'd

| VARIABLES | Non-poor vs poor | Non-poor vs poor vs ultra-poor | Consumption quintiles |
|---|---|---|---|
| Years of education of plot manager | 27.977*** | 27.783*** | 27.197*** |
| | (6.975) [a] | (6.974) | (7.019) |
| African Adult Male Equivalent | 38.665** | 39.349** | 41.661** |
| | (19.066) | (19.117) | (19.140) |
| Dependency ratio (%) | 0.303 | 0.298 | 0.318 |
| | (0.294) | (0.295) | (0.294) |
| Household received extension service for production | 69.447 | 68.195 | 72.840 |
| | (47.410) | (47.446) | (47.069) |
| Distance to boma (Km) | -0.218 | -0.239 | -0.187 |
| | (0.916) | (0.916) | (0.918) |
| Tropic-warm/semi-arid | 266.211*** | 264.337** | 263.274** |
| | (102.891) | (102.819) | (102.957) |
| Tropic-warm/sub-humid | -68.112 | -71.668 | -73.191 |
| | (96.586) | (96.518) | (96.749) |
| Tropic-cool/semiarid | 73.843 | 73.098 | 71.527 |
| | (109.004) | (108.743) | (109.431) |
| Average 12-month total rainfall(mm) for July-June | 1.290*** | 1.302*** | 1.295*** |
| | (0.373) | (0.374) | (0.374) |
| Annual Mean Temperature (°C * 10) | -6.620*** | -6.595*** | -6.599*** |
| | (2.065) | (2.063) | (2.060) |
| Year (2013) | 192.640*** | 191.052*** | 190.778*** |
| | (49.355) | (49.390) | (49.586) |
| Constant | 684.163 | 678.523 | 668.890 |
| | (602.950) | (601.835) | (602.027) |
| Observations | 2,474 | 2,474 | 2,474 |
| Number of groups | 1,072 | 1,072 | 1,072 |

[a] Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4-4 Impact of (asset) Poverty on Nitrogen Use Efficiency

(Dependent variable = maize yield (kg/ha))

| VARIABLES | Non-poor vs poor | Non-poor vs poor vs ultra-poor | Quintiles of wealth index |
|---|---|---|---|
| Nitrogen application rate (Kg/ha) | 9.511*** | 9.538*** | 11.951*** |
| | (1.487) [a] | (1.484) | (1.652) |
| Nitrogen application rate squared | 0.004 | 0.005 | 0.003 |
| | (0.011) | (0.011) | (0.011) |
| Poor * nitrogen application rate | -4.926*** | -3.505*** | -- |
| | (0.915) | (1.116) | |
| Ultra-poor * nitrogen application rate | -- | -6.843*** | -- |
| | | (1.101) | |
| First quintile * nitrogen application rate | -- | -- | -9.246*** |
| | | | (1.413) |
| Second quintile * nitrogen application rate | -- | -- | -5.924*** |
| | | | (1.420) |
| Third quintile * nitrogen application rate | -- | -- | -4.018*** |
| | | | (1.382) |
| Fourth quintile * nitrogen application rate | -- | -- | -2.725** |
| | | | (1.279) |
| Below recommended nitrogen application rate (1/0) | 102.801 | 120.223 | 116.223 |
| | (102.802) | (102.842) | (101.653) |
| Above recommended nitrogen application rate (1/0) | -221.822* | -223.171* | -223.898* |
| | (120.590) | (121.086) | (120.661) |
| Applied basal fertilizer on time (1/0) | 175.645*** | 176.226*** | 182.258*** |
| | (57.819) | (57.598) | (57.297) |
| Applied organic fertilizer (1/0) | 215.521*** | 216.975*** | 209.230*** |
| | (62.129) | (61.885) | (61.685) |
| Seed rate (Kg/ha) | 3.727*** | 3.754*** | 3.721*** |
| | (1.070) | (1.074) | (1.074) |
| Used hybrid seed (1/0) | 75.965* | 76.576* | 69.989 |
| | (44.729) | (44.691) | (44.856) |
| Pure stand (1/0) | -128.170*** | -129.149*** | -131.991*** |
| | (43.278) | (43.183) | (43.101) |
| Plot size (ha) | -1,153.045*** | -1,163.643*** | -1,188.183*** |
| | (268.805) | (268.448) | (267.446) |
| Plot size squared | 513.263*** | 521.923*** | 522.911*** |
| | (189.674) | (189.264) | (188.044) |
| Labor (days) | 1.109*** | 1.114*** | 1.132*** |
| | (0.297) | (0.297) | (0.295) |
| Soil is of good quality (1/0) | 201.091*** | 200.991*** | 200.042*** |
| | (60.077) | (60.162) | (60.221) |
| Soil is of fair quality (1/0) | 171.225*** | 170.074*** | 173.017*** |
| | (57.112) | (57.035) | (56.999) |
| Plot is sloppy (1/0) | -26.440 | -26.292 | -27.196 |
| | (43.096) | (43.089) | (42.546) |
| Plot is swampy (1/0) | -61.347 | -58.271 | -59.931 |
| | (61.022) | (60.906) | (60.637) |
| Soil is sandy clay (1/0) | 47.631 | 48.339 | 48.416 |
| | (44.346) | (44.249) | (43.999) |
| Plot show signs of erosion (1/0) | 29.441 | 31.667 | 30.423 |
| | (53.112) | (53.031) | (52.886) |
| Female plot manager (1/0) | -132.546** | -128.822** | -134.549*** |
| | (52.167) | (52.054) | (51.683) |
| Age of plot manager (years) | -0.669 | -0.724 | -1.228 |
| | (1.649) | (1.643) | (1.629) |

[a] Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4.4: Cont'd

| VARIABLES | Non-poor vs poor | Non-poor vs poor vs ultra-poor | Quintiles of wealth index |
|---|---|---|---|
| Years of education of plot manager | 25.102*** | 24.144*** | 20.660*** |
| | (6.952) [a] | (6.941) | (7.087) |
| African Adult Male Equivalent | 27.262 | 26.967 | 26.243 |
| | (19.290) | (19.264) | (19.263) |
| Dependency ratio (%) | 0.288 | 0.294 | 0.314 |
| | (0.293) | (0.292) | (0.291) |
| Household received extension service for production | 65.813 | 63.811 | 61.877 |
| | (47.025) | (46.911) | (46.657) |
| Distance to boma (Km) | -0.315 | -0.210 | -0.190 |
| | (0.915) | (0.917) | (0.915) |
| Tropic-warm/semiarid | 305.713*** | 319.041*** | 322.959*** |
| | (103.392) | (103.225) | (102.844) |
| Tropic-warm/subhumid | -45.435 | -40.194 | -49.845 |
| | (96.005) | (96.263) | (96.163) |
| Tropic-cool/semiarid | 106.661 | 111.840 | 108.331 |
| | (109.019) | (109.620) | (110.156) |
| Avg 12-month total rainfall(mm) for July-June | 1.293*** | 1.317*** | 1.293*** |
| | (0.372) | (0.371) | (0.371) |
| Annual Mean Temperature (°C * 10) | -7.223*** | -7.364*** | -7.489*** |
| | (2.052) | (2.041) | (2.042) |
| Year (2013) | 192.316*** | 193.375*** | 191.503*** |
| | (49.049) | (48.989) | (48.766) |
| Constant | 883.356 | 870.003 | 974.413 |
| | (598.315) | (598.819) | (598.939) |
| Observations | 2,474 | 2,474 | 2,474 |
| Number of groups | 1,072 | 1,072 | 1,072 |

[a] Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4-5 Factors Influencing the Quantity of Subsidized Fertilizer Acquired by Households[b]

| | Average Partial Effects (APE) |
|---|---|
| Years household head has lived in village during first survey | 0.191*** |
| | (0.067) [a] |
| Wealth index | -0.302 |
| | (1.801) |
| Total landholding (ha) | 4.032 |
| | (2.915) |
| Dependency ratio (%) | -0.004 |
| | (0.034) |
| Household head is female (1/0) | 0.435 |
| | (9.877) |
| Distance to nearest road (Km) | 0.433 |
| | (1.391) |
| Distance to nearest population center of +20,000 people | 0.181 |
| | (0.814) |
| Real price of nitrogen at the time of planting (MKW/ha) | 0.064 |
| | (0.047) |
| Real price of maize during lean season before planting (MKW/ha) | 0.317 |
| | (0.228) |
| 12-month total rainfall (mm) in July-June, starting July 2009 | 0.027 |
| | (0.027) |
| Central region | -1.654 |
| | (4.867) |
| Southern region | 21.705*** |
| | (8.295) |
| Soil quality index | -0.249 |
| | (3.063) |
| Year (2013) | 32.456* |
| | (17.473) |
| Observations | 1,667 |

[a] Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
[b] Based on the tobit estimator

Table 4-6 Double-Hurdle Models of Factors Influencing Demand for Commercial Fertilizer Demand (subsidized fertilizer treated as endogenous)

| VARIABLES | **Hurdle 1** Probability of participating in commercial fertilizer market | **Hurdle 2** Demand for commercial fertilizer upon participation |
|---|---|---|
| | Estimator: Probit | Estimator: Truncated Normal |
| Quantity of subsidized fertilizer acquired by household (kg) | -0.003*** | -0.501** |
| | (0.000) [a] | (0.233) [a] |
| Residual from reduced form equation | 0.007*** | -- |
| | (0.002) | -- |
| Wealth index | -0.018 | -4.488 |
| | (0.020) | (8.753) |
| Landholding (ha) | 0.095*** | 28.025 |
| | (0.032) | (20.461) |
| Dependency ratio (%) | 0.000 | -0.202 |
| | (0.000) | (0.282) |
| Household head is female (1/0) | 0.162 | -41.636 |
| | (0.115) | (67.510) |
| Distance to nearest road (Km) | 0.007 | -13.252*** |
| | (0.016) | (4.328) |
| Distance to nearest population center with +20,000 people | 0.001 | -4.022 |
| | (0.008) | (2.683) |
| Real price of nitrogen at the time of planting (MKW/ha) | 0.000 | 0.860* |
| | (0.001) | (0.470) |
| Real price of maize during lean season before planting (MKW/ha) | -0.000 | 0.882 |
| | (0.003) | (1.693) |
| 12-month total rainfall (mm) in July-June, starting July 2009 | 0.000 | -0.202 |
| | (0.000) | (0.199) |
| Central region | -0.121** | -31.668 |
| | (0.057) | (35.543) |
| Southern region | -0.044 | 4.278 |
| | (0.131) | (67.484) |
| Soil quality index | -0.002 | 14.491 |
| | (0.119) | (17.003) |
| Year (2013) | 0.246 | 188.872 |
| | (0.230) | (127.476) |
| Observations | 1,667 | 646 |

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. [a] Standards errors in hurdle 1 were obtained via bootstrapping at 250 repetitions to account for first-stage estimation. The coefficients in both hurdles were obtained using *margins* command in Stata.

Table 4-7 Average Partial Effects (APE) of Subsidized Fertilizer on Commercial Fertilizer Demand across Different poverty Groups

| | **Consumption poverty** | **Asset poverty** |
|---|---|---|
| **Poverty category 1** | | |
| Non-poor | -0.874*** | -0.911*** |
| | (0.170) [a] | (0.178) |
| Poor | -0.830*** | -0.781*** |
| | (0.153) | (0.145) |
| **Poverty category 2** | | |
| Non-poor | 0.874*** | -0.911*** |
| | (0.170) | (0.178) |
| Poor | 0.840*** | -0.817*** |
| | (0.156) | (0.150) |
| Ultra-poor | 0.805*** | -0.748*** |
| | (0.149) | (0.142) |
| **Poverty category 3** | | |
| First quintile | -0.819*** | -0.748*** |
| | (0.151) | (0.142) |
| Second quintile | -0.852*** | -0.817*** |
| | (0.584) | (0.150) |
| Third quintile | -0.852*** | -0.868*** |
| | (0.162) | (0.165) |
| Fourth quintile | 0.900*** | -0.949*** |
| | (0.177) | (0.177) |
| Fifth quintile | 0.868*** | -0.918*** |
| | (0.176) | (0.204) |

*** implies significant at 1% level. [a] Values in parenthesis are standard errors obtained via bootstrapping at 250 repetitions. The mean APE is -0.858 for the entire sample.

Table 4-8 Difference in Crowding Out Estimates Across Poverty Groups

| | Consumption poverty | Asset poverty |
|---|---|---|
| Poverty category 1 | | |
| Non-poor vs Poor | -0.045*** | -0.130*** |
| | (5.422%) [a] | (16.645%) |
| Poverty category 2 | | |
| Non-poor vs Poor | -0.034** | -0.095*** |
| | (4.048%) | (11.628%) |
| Non-poor vs Ultra-poor | -0.069*** | -0.163*** |
| | (8.571%) | (21.791%) |
| Poor vs Ultra-poor | -0.035 * | -0.069*** |
| | (4.348%) | (9.225%) |

***, **, and * imply significant difference at 1%, 5% and 10% levels respectively. [a] Values in parenthesis are estimates of percentage difference in crowding out.

Table 4-9 Estimates of $\Delta \boldsymbol{NUE_{p1,p0}}$, $\Delta \boldsymbol{CO_{p1,p0}}$ and $\boldsymbol{NUE_{p0}}$ Across Poverty Groups

| | Consumption poverty | | | Asset poverty | | |
|---|---|---|---|---|---|---|
| | $\Delta NUE_{p1,p0}$ | $\Delta CO_{p1,p0}$ | $NUE_{p0}$ | $\Delta NUE_{p1,p0}$ | $\Delta CO_{p1,p0}$ | $NUE_{p0}$ |
| **Poverty category 1** | | | | | | |
| Non-poor vs Poor | 3.376*** | -0.045*** | 5.342 | 4.926*** | -0.130*** | 4.585 |
| **Poverty category 2** | | | | | | |
| Non-poor vs Poor | 3.019*** | -0.034** | 5.720 | 3.505*** | -0.095*** | 6.033 |
| Non-poor vs Ultra-poor | 4.465*** | -0.069*** | 4.274 | 6.843*** | -0.163*** | 2.695 |
| Poor vs Ultra-poor | 1.445 | -0.035* | 4.274 | 3.337*** | -0.069*** | 2.696 |

***, **, and * imply significant difference at 1%, 5% and 10% levels respectively.

Table 4-10 : Estimates of $\boldsymbol{NG_{yield,p}}$

| | Consumption poverty | Asset poverty |
|---|---|---|
| Poverty category 1 | | |
| Non-poor vs Poor | 3.136*** | 4.330*** |
| | (0.123) | (0.144) |
| Poverty category 2 | | |
| Non-poor vs Poor | 2.825*** | 2.932*** |
| | (0.111) | (0.134) |
| Non-poor vs Ultra-poor | 4.170*** | 6.404*** |
| | (0.186) | (0.214) |
| Poor vs Ultra-poor | 1.295* | 3.151** |
| | (0.009) | (0.116) |

*** implies significant at 1% level. [a] Values in parenthesis are standard errors obtained via bootstrapping at 250 repetitions.

# APPENDICES

# Appendix A

Table 2.A1: Effect of Maize Yield (Kg/ha) on Poverty

| Dependent variable: maize yield | Log consumption expenditure | Log relative deprivation | Poverty gap[a] | Poverty severity[a] |
|---|---|---|---|---|
| | HH fixed effects | HH fixed effects | logit & fractional logit with MC Device | logit & fractional logit with MC Device |
| | Coefficient | Coefficient | Unconditional APE | Unconditional APE |
| Log of maize yield (Kg/ha) | 0.132*** | -0.058*** | -0.034*** | -0.017*** |
| | (0.020) | (0.009) | (0.006) | (0.004) |
| Log of value of other crops (MKW/ha) | 0.002 | -0.001 | -0.001 | -0.001 |
| | (0.003) | (0.002) | (0.001) | (0.000) |
| Log net income from tree crops (MKW) | 0.002 | -0.000 | -0.001 | -0.000 |
| | (0.003) | (0.001) | (0.001) | (0.001) |
| Number of livestock | 0.043*** | -0.020** | -0.009 | -0.002 |
| | (0.014) | (0.008) | (0.011) | (0.007) |
| Log of net income from off-farm activities | 0.003 | -0.002 | -0.001 | -0.000 |
| | (0.002) | (0.002) | (0.001) | (0.000) |
| Log of agricultural wage | -0.002 | 0.001 | -0.000 | 0.000 |
| | (0.003) | (0.001) | (0.001) | (0.000) |
| Other income sources (1/0) | 0.003 | -0.011 | 0.001 | 0.000 |
| | (0.028) | (0.014) | (0.009) | (0.006) |
| Household size | -0.148*** | 0.068*** | 0.031*** | 0.016*** |
| | (0.009) | (0.006) | (0.003) | (0.002) |
| Dependency ratio (%) | -0.001*** | 0.000*** | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Male-headed household (1/0) | 0.018 | -0.007 | -0.011 | -0.003 |
| | (0.051) | (0.030) | (0.017) | (0.009) |
| Age of Household head (years) | 0.009 | -0.006 | 0.002 | 0.002** |
| | (0.007) | (0.004) | (0.001) | (0.001) |
| Age of household head squared | -0.000* | 0.000* | -0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Education of most educated HH member (years) | 0.008 | -0.001 | -0.005* | -0.004** |
| | (0.010) | (0.005) | (0.003) | (0.002) |
| Log of landholding (Ha) | 0.129*** | -0.048*** | -0.047*** | -0.024*** |
| | (0.030) | (0.014) | (0.006) | (0.004) |
| Owns crop storage house (1/0) | 0.109*** | -0.048** | -0.030** | -0.015** |
| | (0.033) | (0.018) | (0.013) | (0.007) |
| Accessed credit (1/0) | 0.049 | -0.021 | -0.011 | -0.014** |
| | (0.031) | (0.019) | (0.011) | (0.006) |
| Accessed extension for production (1/0) | 0.008 | 0.005 | -0.018* | -0.012** |
| | (0.028) | (0.013) | (0.010) | (0.006) |
| Distance to road (Km) | -0.002 | 0.002 | 0.000 | 0.001 |
| | (0.005) | (0.003) | (0.002) | (0.002) |
| Distance to tobacco auction (Km) | -0.001 | 0.001 | 0.001 | 0.001* |
| | (0.002) | (0.001) | (0.001) | (0.000) |
| Distance to boma (Km) | 0.002** | -0.000 | -0.001*** | -0.000** |
| | (0.001) | (0.000) | (0.000) | (0.000) |
| Distance to weekly market (Km) | 0.003 | -0.001 | -0.001 | -0.000 |
| | (0.003) | (0.001) | (0.001) | (0.000) |
| Log of price of Urea fertilizer (MKW/Kg) | 0.127 | -0.049 | -0.076* | -0.036 |
| | (0.143) | (0.062) | (0.045) | (0.028) |
| Laspeyre's spatial price index | -0.007*** | 0.002* | 0.003*** | 0.002*** |
| | (0.003) | (0.001) | (0.001) | (0.000) |
| Northern region | -0.196 | 0.141 | -0.283* | -0.296*** |
| | (0.230) | (0.115) | (0.157) | (0.099) |
| Southern region | -0.060 | 0.019 | -0.129 | -0.181** |
| | (0.177) | (0.102) | (0.127) | (0.081) |
| Graded/Graveled | -0.077 | 0.033 | 0.021 | 0.001 |
| | (0.098) | (0.059) | (0.016) | (0.011) |
| Dirt road (maintained) | -0.015 | 0.017 | -0.003 | -0.016 |
| | (0.105) | (0.061) | (0.020) | (0.012) |
| Dirt track | 0.096 | -0.020 | -0.027 | -0.028** |
| | (0.128) | (0.065) | (0.028) | (0.014) |
| Agro-ecological zone fixed effect | Yes | Yes | Yes | Yes |
| Year (1 = 2013) | 0.135*** | -0.051*** | -0.024** | -0.010** |
| | (0.036) | (0.015) | (0.010) | (0.005) |
| Constant | 11.641*** | 11.582*** | | |
| | (0.902) | (0.391) | | |
| Time averages (CRE) | NA | NA | Yes | Yes |
| Observations | 2,023 | 2,023 | 2,023 | 2,023 |
| R-squared | 0.825 | 0.804 | | |

*** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses. APE means average partial effect

[a] Estimation was based on a two-part model: first part, logit of probability of being poor; and second part, fractional model of extent of poverty.

Table 2.A2: Effect of Maize Yield (Kg/ha) on Food Security

| | Log caloric intake | Log relative deprivation |
|---|---|---|
| | HH fixed effects | HH fixed effects |
| | Coefficient | Coefficient |
| Log of maize yield (Kg/ha) | 0.060** | -0.036 |
| | (0.023) | (0.024) |
| Log of value of other crops (MKW/ha) | 0.005 | -0.002 |
| | (0.004) | (0.004) |
| Log net income from tree crops (MKW) | 0.002 | 0.001 |
| | (0.003) | (0.004) |
| Number of livestock | 0.024 | 0.000 |
| | (0.025) | (0.027) |
| Log of net income from off-farm activities | -0.003 | 0.001 |
| | (0.002) | (0.003) |
| Log of agricultural wage | -0.002 | 0.001 |
| | (0.003) | (0.004) |
| Other income sources (1/0) | 0.024 | -0.008 |
| | (0.030) | (0.037) |
| Household size | -0.104*** | 0.103*** |
| | (0.011) | (0.015) |
| Dependency ratio (%) | -0.001*** | 0.001*** |
| | (0.000) | (0.000) |
| Male-headed household (1/0) | -0.029 | 0.052 |
| | (0.050) | (0.061) |
| Age of Household head (years) | 0.012 | -0.011 |
| | (0.008) | (0.008) |
| Age of household head squared | -0.000* | 0.000 |
| | (0.000) | (0.000) |
| Education of most educated HH member (years) | -0.003 | 0.018 |
| | (0.009) | (0.013) |
| Log of landholding (Ha) | 0.054** | -0.041 |
| | (0.026) | (0.033) |
| Owns crop storage house (1/0) | 0.042 | -0.023 |
| | (0.034) | (0.037) |
| Accessed credit (1/0) | 0.033 | -0.008 |
| | (0.033) | (0.046) |
| Accessed extension for production (1/0) | 0.008 | -0.014 |
| | (0.026) | (0.034) |
| Distance to road (Km) | 0.002 | -0.004 |
| | (0.004) | (0.008) |
| Distance to tobacco auction (Km) | -0.002 | 0.001 |
| | (0.001) | (0.002) |
| Distance to boma (Km) | 0.001 | 0.000 |
| | (0.001) | (0.001) |
| Distance to weekly market (Km) | 0.001 | -0.001 |
| | (0.003) | (0.003) |
| Log of price of Urea fertilizer (MKW/Kg) | 0.256 | -0.097 |
| | (0.156) | (0.179) |
| Laspeyre's spatial price index | 0.005* | -0.007** |
| | (0.003) | (0.003) |
| Northern region | 0.071 | -0.218 |
| | (0.250) | (0.286) |
| Southern region | -0.008 | -0.249 |
| | (0.252) | (0.266) |
| Graded/Graveled | -0.050 | 0.115 |
| | (0.088) | (0.081) |
| Dirt road (maintained) | 0.031 | -0.004 |
| | (0.088) | (0.082) |
| Dirt track | 0.157 | -0.031 |
| | (0.105) | (0.091) |
| Agro-ecological zone fixed effect | Yes | Yes |
| Year (1= 2013) | 0.052 | 0.041 |
| | (0.036) | (0.035) |
| Constant | 5.555*** | 8.579*** |
| | (0.893) | (1.137) |
| Time averages (CRE) | NA | NA |
| Observations | 2,023 | 1,935 |
| R-squared | 0.703 | 0.691 |

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses

Table 2.A3: Effect of Value of Crops (MKW/ha) on Poverty

| | Log consumption Expenditure | Log relative Deprivation | Poverty Gap[a] | Poverty Severity[a] |
|---|---|---|---|---|
| | HH fixed effects | HH fixed effects | logit & fractional logit with MC Device | logit & fractional logit with MC Device |
| | Coefficient | Coefficient | Unconditional APE | Unconditional APE |
| Log value of crops (MKW/ha) | 0.096*** | -0.042*** | -0.019*** | -0.008*** |
| | (0.017) | (0.007) | (0.004) | (0.002) |
| Log net income from tree crops (MKW) | 0.003 | -0.001 | -0.001 | -0.000 |
| | (0.003) | (0.001) | (0.001) | (0.001) |
| Number of livestock | 0.040*** | -0.019** | -0.009 | -0.003 |
| | (0.014) | (0.008) | (0.012) | (0.007) |
| Log of net income from off-farm activities | 0.003 | -0.002 | -0.001 | -0.000 |
| | (0.002) | (0.002) | (0.001) | (0.000) |
| Log of agricultural wage | -0.001 | 0.001 | -0.000 | 0.000 |
| | (0.003) | (0.001) | (0.001) | (0.000) |
| Other income sources (1/0) | 0.007 | -0.012 | 0.002 | 0.001 |
| | (0.027) | (0.013) | (0.009) | (0.006) |
| Household size | -0.151*** | 0.069*** | 0.032*** | 0.015*** |
| | (0.009) | (0.006) | (0.003) | (0.002) |
| Dependency ratio (%) | -0.001*** | 0.000*** | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Male-headed household (1/0) | 0.031 | -0.013 | -0.013 | -0.005 |
| | (0.053) | (0.030) | (0.017) | (0.009) |
| Age of Household head (years) | 0.010 | -0.006 | 0.002 | 0.002* |
| | (0.007) | (0.004) | (0.001) | (0.001) |
| Age of household head squared | -0.000* | 0.000* | -0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Education of most educated HH member (years) | 0.007 | -0.001 | -0.004 | -0.003* |
| | (0.010) | (0.005) | (0.003) | (0.002) |
| Log of landholding (Ha) | 0.092*** | -0.031** | -0.041*** | -0.021*** |
| | (0.026) | (0.013) | (0.006) | (0.003) |
| Owns crop storage house (1/0) | 0.111*** | -0.049** | -0.029** | -0.015** |
| | (0.033) | (0.020) | (0.013) | (0.008) |
| Accessed credit (1/0) | 0.050 | -0.021 | -0.013 | -0.015*** |
| | (0.032) | (0.020) | (0.010) | (0.006) |
| Accessed extension for production (1/0) | 0.004 | 0.007 | -0.015 | -0.010* |
| | (0.028) | (0.013) | (0.011) | (0.006) |
| Distance to road (Km) | -0.003 | 0.003 | 0.000 | 0.001 |
| | (0.005) | (0.003) | (0.002) | (0.002) |
| Distance to tobacco auction (Km) | -0.002 | 0.001 | 0.001* | 0.001** |
| | (0.002) | (0.001) | (0.000) | (0.000) |
| Distance to boma (Km) | 0.002** | -0.000 | -0.001*** | -0.000* |
| | (0.001) | (0.000) | (0.000) | (0.000) |
| Distance to weekly market (Km) | 0.003 | -0.001 | -0.001 | -0.000 |
| | (0.003) | (0.001) | (0.001) | (0.000) |
| Log of price of Urea fertilizer (MKW/Kg) | 0.168 | -0.070 | -0.081* | -0.039 |
| | (0.143) | (0.064) | (0.046) | (0.028) |
| Laspeyre's spatial price index | -0.009*** | 0.003** | 0.004*** | 0.002*** |
| | (0.003) | (0.001) | (0.001) | (0.000) |
| Northern region | -0.262 | 0.171 | -0.268* | -0.291*** |
| | (0.226) | (0.119) | (0.154) | (0.094) |
| Southern region | -0.044 | 0.013 | -0.135 | -0.187** |
| | (0.163) | (0.101) | (0.123) | (0.077) |
| Graded/Graveled | -0.076 | 0.034 | 0.020 | -0.000 |
| | (0.101) | (0.060) | (0.018) | (0.010) |
| Dirt road (maintained) | -0.042 | 0.030 | 0.001 | -0.015 |
| | (0.109) | (0.062) | (0.023) | (0.012) |
| Dirt track | 0.046 | 0.004 | -0.019 | -0.024* |
| | (0.129) | (0.066) | (0.029) | (0.014) |
| Agro-ecological zone fixed effect | Yes | Yes | Yes | Yes |
| Year (1 = 2013) | 0.133*** | -0.050*** | -0.025** | -0.011** |
| | (0.036) | (0.015) | (0.010) | (0.005) |
| Constant | 11.532*** | 11.647*** | | |
| | (0.865) | (0.379) | | |
| Time averages (CRE) | NA | NA | Yes | Yes |
| Observations | 2,023 | 2,023 | 2,023 | 2,023 |
| R-squared | 0.822 | 0.802 | | |

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses

[a] Estimation was based on a two-part model: first part, CRE logit of probability of being poor; and second part, CRE fractional model of extent of poverty.

Table 2.A4: Effect of Value of Crops (MKW/ha) on Food Security

| | Log of Caloric intake | Log relative Deprivation |
|---|---|---|
| | HH fixed effects | HH fixed effects |
| | Coefficient | Coefficient |
| Log value of crops (MKW/ha) | 0.054*** | -0.040* |
| | (0.019) | (0.020) |
| Log net income from tree crops (MKW) | 0.002 | 0.000 |
| | (0.003) | (0.004) |
| Number of livestock | 0.022 | 0.002 |
| | (0.026) | (0.027) |
| Log of net income from off-farm activities | -0.003 | 0.000 |
| | (0.002) | (0.003) |
| Log of agricultural wage | -0.001 | 0.001 |
| | (0.003) | (0.004) |
| Other income sources (1/0) | 0.025 | -0.010 |
| | (0.030) | (0.036) |
| Household size | -0.106*** | 0.104*** |
| | (0.011) | (0.015) |
| Dependency ratio (%) | -0.001*** | 0.001*** |
| | (0.000) | (0.000) |
| Male-headed household (1/0) | -0.029 | 0.050 |
| | (0.051) | (0.061) |
| Age of Household head (years) | 0.013 | -0.011 |
| | (0.008) | (0.008) |
| Age of household head squared | -0.000* | 0.000 |
| | (0.000) | (0.000) |
| Education of most educated HH member (years) | -0.004 | 0.018 |
| | (0.009) | (0.013) |
| Log of landholding (Ha) | 0.045* | -0.035 |
| | (0.025) | (0.033) |
| Owns crop storage house (1/0) | 0.041 | -0.022 |
| | (0.033) | (0.038) |
| Accessed credit (1/0) | 0.036 | -0.009 |
| | (0.032) | (0.044) |
| Accessed extension for production (1/0) | 0.006 | -0.012 |
| | (0.026) | (0.034) |
| Distance to road (Km) | 0.001 | -0.004 |
| | (0.004) | (0.008) |
| Distance to tobacco auction (Km) | -0.002 | 0.001 |
| | (0.001) | (0.002) |
| Distance to boma (Km) | 0.001 | 0.000 |
| | (0.001) | (0.001) |
| Distance to weekly market (Km) | 0.001 | -0.001 |
| | (0.003) | (0.003) |
| Log of price of Urea fertilizer (MKW/Kg) | 0.256 | -0.107 |
| | (0.162) | (0.184) |
| Laspeyres spatial price index | 0.005 | -0.007** |
| | (0.003) | (0.003) |
| Northern region | 0.043 | -0.183 |
| | (0.250) | (0.281) |
| Southern region | 0.000 | -0.239 |
| | (0.258) | (0.267) |
| Graded/Graveled | -0.045 | 0.119 |
| | (0.087) | (0.079) |
| Dirt road (maintained) | 0.025 | 0.007 |
| | (0.090) | (0.080) |
| Dirt track | 0.143 | -0.014 |
| | (0.104) | (0.088) |
| Agro-ecological zone fixed effect | Yes | Yes |
| Year (1= 2013) | 0.054 | 0.041 |
| | (0.036) | (0.036) |
| Constant | 5.530*** | 8.716*** |
| | (0.907) | (1.144) |
| Time averages (CRE) | NA | NA |
| Observations | 2,023 | 1,935 |
| R-squared | 0.702 | 0.691 |

*** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses

Table 2.A5: Effect of Maize Yield (Kg/ha) on Composite Welfare

| | Estimate | Average Marginal Effects | | |
|---|---|---|---|---|
| | | Category 1 | Category 2 | Category 3 |
| Log of maize yield (Kg/ha) | 0.204*** | -0.057*** | -0.003 | 0.060*** |
| | (0.061) | (0.017) | (0.002) | (0.018) |
| Log of value of other crops (MKW/ha) | 0.011 | -0.003 | -0.000 | 0.003 |
| | (0.010) | (0.003) | (0.000) | (0.003) |
| Log net income from tree crops (MKW) | -0.002 | 0.001 | 0.000 | -0.001 |
| | (0.008) | (0.002) | (0.000) | (0.002) |
| Number of livestock | 0.124 | -0.035 | -0.002 | 0.037 |
| | (0.084) | (0.024) | (0.001) | (0.025) |
| Log of net income from off-farm activities | -0.003 | 0.001 | 0.000 | -0.001 |
| | (0.006) | (0.002) | (0.000) | (0.002) |
| Log of agricultural wage | -0.002 | 0.001 | 0.000 | -0.001 |
| | (0.008) | (0.002) | (0.000) | (0.002) |
| Other income sources (1/0) | 0.018 | -0.005 | -0.000 | 0.005 |
| | (0.086) | (0.024) | (0.001) | (0.025) |
| Household size | -0.297*** | 0.084*** | 0.004* | -0.088*** |
| | (0.036) | (0.010) | (0.002) | (0.010) |
| Dependency ratio (%) | -0.002*** | 0.001*** | 0.000 | -0.001*** |
| | (0.001) | (0.000) | (0.000) | (0.000) |
| Male-headed household (1/0) | -0.035 | 0.010 | 0.000 | -0.010 |
| | (0.135) | (0.038) | (0.002) | (0.040) |
| Age of Household head (years) | 0.005 | -0.001 | -0.000 | 0.002 |
| | (0.012) | (0.003) | (0.000) | (0.004) |
| Age of household head squared | -0.000 | 0.000 | 0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Education of most educated HH member (years) | 0.026 | -0.007 | -0.000 | 0.008 |
| | (0.022) | (0.006) | (0.000) | (0.007) |
| Log of landholding (Ha) | 0.291*** | -0.082*** | -0.004* | 0.086*** |
| | (0.055) | (0.015) | (0.002) | (0.016) |
| Owns crop storage house (1/0) | -0.006 | 0.002 | 0.000 | -0.002 |
| | (0.100) | (0.028) | (0.001) | (0.029) |
| Accessed credit (1/0) | 0.040 | -0.011 | -0.001 | 0.012 |
| | (0.101) | (0.028) | (0.001) | (0.030) |
| Accessed extension for production (1/0) | 0.074 | -0.021 | -0.001 | 0.022 |
| | (0.069) | (0.020) | (0.001) | (0.020) |
| Distance to road (Km) | 0.010 | -0.003 | -0.000 | 0.003 |
| | (0.014) | (0.004) | (0.000) | (0.004) |
| Distance to tobacco auction (Km) | 0.005 | -0.001 | -0.000 | 0.001 |
| | (0.004) | (0.001) | (0.000) | (0.001) |
| Distance to boma (Km) | 0.004** | -0.001** | -0.000 | 0.001** |
| | (0.002) | (0.001) | (0.000) | (0.001) |
| Distance to weekly market (Km) | 0.006 | -0.002 | -0.000 | 0.002 |
| | (0.010) | (0.003) | (0.000) | (0.003) |
| Log of price of Urea fertilizer (MKW/Kg) | 0.699* | -0.197* | -0.009 | 0.206* |
| | (0.368) | (0.104) | (0.008) | (0.109) |
| Laspeyre's spatial price index | 0.001 | -0.000 | -0.000 | 0.000 |
| | (0.007) | (0.002) | (0.000) | (0.002) |
| Northern region | 0.671 | -0.189 | -0.009 | 0.198 |
| | (0.654) | (0.184) | (0.011) | (0.194) |
| Southern region | 0.363 | -0.102 | -0.005 | 0.107 |
| | (0.697) | (0.196) | (0.010) | (0.206) |
| Graded/Graveled | -0.212 | 0.060 | 0.003 | -0.063 |
| | (0.353) | (0.100) | (0.005) | (0.104) |
| Dirt road (maintained) | -0.135 | 0.038 | 0.002 | -0.040 |
| | (0.363) | (0.102) | (0.005) | (0.107) |
| Dirt track | 0.263 | -0.074 | -0.004 | 0.078 |
| | (0.427) | (0.120) | (0.006) | (0.126) |
| Agro-ecological zone fixed effect | Yes | Yes | Yes | Yes |
| Year (1=2010) | -0.202** | 0.057** | 0.003 | -0.060** |
| | (0.089) | (0.025) | (0.002) | (0.026) |
| Constant cut1 | 0.444 | | | |
| | (2.417) | | | |
| Constant cut2 | 1.415 | | | |
| | (2.411) | | | |
| Time averages (CRE) | Yes | Yes | Yes | Yes |
| Observations | 2,023 | 2,023 | 2,023 | 2,023 |

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses

Category 1 = Poor and food insecure; Category 2 = Non-poor but food insecure or poor but food secured; Category 3 = Non-poor and food secured

Table 2.A6: Effect of Value of Crops (MKW/ha) on Composite Welfare

| | Estimate | Average Partial Effects | | |
|---|---|---|---|---|
| | | Category 1 | Category 2 | Category 3 |
| Log value of crops (MKW/ha) | 0.154*** | -0.043*** | -0.002 | 0.046*** |
| | (0.038) | (0.010) | (0.001) | (0.011) |
| Log net income from tree crops (MKW) | -0.001 | 0.000 | 0.000 | -0.000 |
| | (0.008) | (0.002) | (0.000) | (0.002) |
| Number of livestock | 0.120 | -0.034 | -0.002 | 0.035 |
| | (0.084) | (0.024) | (0.001) | (0.025) |
| Log of net income from farm off- activities | -0.002 | 0.001 | 0.000 | -0.001 |
| | (0.005) | (0.002) | (0.000) | (0.002) |
| Log of agricultural wage | -0.002 | 0.000 | 0.000 | -0.000 |
| | (0.008) | (0.002) | (0.000) | (0.002) |
| Other income sources (1/0) | 0.018 | -0.005 | -0.000 | 0.005 |
| | (0.086) | (0.024) | (0.001) | (0.026) |
| Household size | -0.301*** | 0.085*** | 0.004* | -0.089*** |
| | (0.036) | (0.010) | (0.002) | (0.010) |
| Dependency ratio (%) | -0.002*** | 0.001*** | 0.000 | -0.001*** |
| | (0.001) | (0.000) | (0.000) | (0.000) |
| Male-headed household (1/0) | -0.029 | 0.008 | 0.000 | -0.009 |
| | (0.140) | (0.039) | (0.002) | (0.041) |
| Age of Household head (years) | 0.006 | -0.002 | -0.000 | 0.002 |
| | (0.012) | (0.003) | (0.000) | (0.003) |
| Age of household head squared | -0.000 | 0.000 | 0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Education of most educated HH member (years) | 0.023 | -0.006 | -0.000 | 0.007 |
| | (0.022) | (0.006) | (0.000) | (0.007) |
| Log of landholding (Ha) | 0.252*** | -0.071*** | -0.003* | 0.074*** |
| | (0.052) | (0.015) | (0.002) | (0.015) |
| Owns crop storage house (1/0) | -0.004 | 0.001 | 0.000 | -0.001 |
| | (0.097) | (0.027) | (0.001) | (0.029) |
| Accessed credit (1/0) | 0.054 | -0.015 | -0.001 | 0.016 |
| | (0.102) | (0.029) | (0.001) | (0.030) |
| Accessed extension for production (1/0) | 0.068 | -0.019 | -0.001 | 0.020 |
| | (0.070) | (0.020) | (0.001) | (0.021) |
| Distance to road (Km) | 0.009 | -0.002 | -0.000 | 0.003 |
| | (0.014) | (0.004) | (0.000) | (0.004) |
| Distance to tobacco auction (Km) | 0.004 | -0.001 | -0.000 | 0.001 |
| | (0.004) | (0.001) | (0.000) | (0.001) |
| Distance to boma (Km) | 0.004** | -0.001** | -0.000 | 0.001** |
| | (0.002) | (0.001) | (0.000) | (0.001) |
| Distance to weekly market (Km) | 0.007 | -0.002 | -0.000 | 0.002 |
| | (0.010) | (0.003) | (0.000) | (0.003) |
| Log of price of Urea fertilizer (MKW/Kg) | 0.714* | -0.201* | -0.010 | 0.211* |
| | (0.383) | (0.108) | (0.008) | (0.114) |
| Laspeyre's spatial price index | -0.001 | 0.000 | 0.000 | -0.000 |
| | (0.007) | (0.002) | (0.000) | (0.002) |
| Northern region | 0.583 | -0.164 | -0.008 | 0.172 |
| | (0.642) | (0.181) | (0.010) | (0.190) |
| Southern region | 0.380 | -0.107 | -0.005 | 0.112 |
| | (0.688) | (0.194) | (0.010) | (0.203) |
| Graded/Graveled | -0.193 | 0.054 | 0.003 | -0.057 |
| | (0.353) | (0.099) | (0.005) | (0.104) |
| Dirt road (maintained) | -0.156 | 0.044 | 0.002 | -0.046 |
| | (0.367) | (0.103) | (0.005) | (0.108) |
| Dirt track | 0.224 | -0.063 | -0.003 | 0.066 |
| | (0.428) | (0.121) | (0.006) | (0.126) |
| Agro-ecological zone fixed effect | Yes | Yes | Yes | Yes |
| Year (1 = 2013) | 0.207** | -0.058** | -0.003 | 0.061** |
| | (0.089) | (0.025) | (0.002) | (0.026) |
| Constant cut1 | 1.387 | | | |
| | (2.446) | | | |
| Constant cut2 | 2.359 | | | |
| | (2.440) | | | |
| Time averages (CRE) | Yes | Yes | Yes | Yes |
| Observations | 2,023 | 2,023 | 2,023 | 2,023 |

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses

Category 1 = Poor and food insecure; Category 2 = Non-poor but food insecure or poor but food secured; Category 3 = Non-poor and food secured

Table 2.A7: Testing for Endogeneity of Agricultural Productivity Using Control Function Approach

| | Dependent variable | | |
|---|---|---|---|
| | Log of maize yield | Log Consumption expenditure | Log caloric intake |
| Log of maize yield (Kg/ha) | | 0.162 | -0.036 |
| | | (0.106) | (0.180) |
| Log of duration of photosynthetic period (days) | -0.677** | | |
| | (0.256) | | |
| Residuals from auxiliary regression | | -0.031 | 0.100 |
| | | (0.103) | (0.176) |
| Log of value of other crops (MKW/ha) | 0.017*** | 0.002 | 0.007 |
| | (0.006) | (0.004) | (0.004) |
| Log net income from tree crops (MKW) | 0.019*** | 0.002 | 0.004 |
| | (0.005) | (0.003) | (0.005) |
| Number of livestock | 0.060 | 0.041*** | 0.029 |
| | (0.040) | (0.015) | (0.028) |
| Log of net income from off-farm activities | -0.005 | 0.003 | -0.003 |
| | (0.004) | (0.002) | (0.002) |
| Log of agricultural wage | -0.006 | -0.002 | -0.002 |
| | (0.006) | (0.003) | (0.003) |
| Other income sources (1/0) | -0.003 | 0.005 | 0.020 |
| | (0.061) | (0.030) | (0.030) |
| Household size | 0.009 | -0.148*** | -0.103*** |
| | (0.024) | (0.009) | (0.011) |
| Dependency ratio (%) | -0.000 | -0.001*** | -0.001*** |
| | (0.000) | (0.000) | (0.000) |
| Male-headed household (1/0) | 0.138 | 0.014 | -0.014 |
| | (0.095) | (0.053) | (0.050) |
| Age of Household head (years) | 0.027 | 0.008 | 0.015* |
| | (0.018) | (0.007) | (0.008) |
| Age of household head squared | -0.000 | -0.000* | -0.000** |
| | (0.000) | (0.000) | (0.000) |
| Education of most educated HH member (years) | -0.003 | 0.008 | -0.003 |
| | (0.014) | (0.010) | (0.009) |
| Log of landholding (Ha) | -0.469*** | 0.144** | 0.009 |
| | (0.063) | (0.059) | (0.088) |
| Owns crop storage house (1/0) | 0.051 | 0.107*** | 0.049 |
| | (0.056) | (0.034) | (0.036) |
| Accessed credit (1/0) | 0.029 | 0.047 | 0.038 |
| | (0.074) | (0.031) | (0.033) |
| Accessed extension for production (1/0) | 0.043 | 0.007 | 0.011 |
| | (0.052) | (0.028) | (0.025) |
| Distance to road (Km) | 0.008 | -0.002 | 0.002 |
| | (0.010) | (0.005) | (0.004) |
| Distance to tobacco auction (Km) | -0.003 | -0.001 | -0.002 |
| | (0.003) | (0.002) | (0.002) |
| Distance to boma (Km) | -0.002 | 0.002** | 0.001 |
| | (0.001) | (0.001) | (0.001) |
| Distance to weekly market (Km) | 0.001 | 0.002 | 0.001 |
| | (0.009) | (0.003) | (0.004) |
| Log of price of Urea fertilizer (MKW/Kg) | 0.448 | 0.114 | 0.299 |
| | (0.328) | (0.148) | (0.186) |
| Laspeyre's spatial price index | -0.015** | -0.007* | 0.003 |
| | (0.007) | (0.003) | (0.005) |
| Northern region | -0.015 | -0.199 | 0.078 |
| | (0.836) | (0.230) | (0.249) |
| Southern region | 0.592 | -0.076 | 0.043 |
| | (0.628) | (0.174) | (0.267) |
| Tropical-warm/sub humid | 0.257 | 0.209 | 0.112 |
| | (0.182) | (0.143) | (0.118) |
| Tropical-cool/semiarid | -0.260 | 0.006 | 0.056 |
| | (0.227) | (0.096) | (0.150) |
| Tropical-cool/sub humid | 0.147 | -0.540** | 0.250 |
| | (0.349) | (0.209) | (0.242) |
| Graded/Graveled | 0.344** | -0.086 | -0.021 |
| | (0.171) | (0.105) | (0.108) |
| Dirt road (maintained) | 0.185 | -0.019 | 0.045 |
| | (0.197) | (0.106) | (0.095) |
| Dirt track | 0.141 | 0.095 | 0.161 |
| | (0.239) | (0.128) | (0.105) |
| Year (2013) | -0.051 | 0.136*** | 0.047 |
| | (0.071) | (0.037) | (0.039) |
| Constant | 7.617*** | 11.243*** | 6.568*** |
| | (1.814) | (0.982) | (1.206) |
| Observations | 2,023 | 2,023 | 2,023 |
| R-squared | 0.740 | 0.825 | 0.703 |

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses

Table 2.A8: Testing for Endogeneity of Agricultural Productivity Using Control Function Approach

| | Dependent variable | | |
|---|---|---|---|
| VARIABLES | Log of value of output per ha | Log consumption expenditure | Log caloric intake |
| Log of value of output per ha | | 0.195 | -0.041 |
| | | (0.140) | (0.215) |
| Log of duration of photosynthetic period (days) | -0.568** | | |
| | (0.233) | | |
| Residuals from auxiliary regression | | -0.100 | 0.097 |
| | | (0.141) | (0.213) |
| Log net income from tree crops (MKW) | 0.015** | 0.002 | 0.004 |
| | (0.006) | (0.003) | (0.005) |
| Number of livestock | 0.121*** | 0.028 | 0.034 |
| | (0.039) | (0.022) | (0.037) |
| Log of net income from off-farm activities | -0.011** | 0.004* | -0.004 |
| | (0.005) | (0.003) | (0.003) |
| Log of agricultural wage | -0.014** | -0.000 | -0.003 |
| | (0.006) | (0.003) | (0.005) |
| Other income sources (1/0) | -0.080 | 0.018 | 0.014 |
| | (0.090) | (0.034) | (0.036) |
| Household size | 0.052* | -0.157*** | -0.100*** |
| | (0.027) | (0.013) | (0.017) |
| Dependency ratio (%) | -0.000 | -0.001*** | -0.001*** |
| | (0.000) | (0.000) | (0.000) |
| Male-headed household (1/0) | 0.007 | 0.029 | -0.027 |
| | (0.131) | (0.052) | (0.050) |
| Age of Household head (years) | 0.024 | 0.008 | 0.015* |
| | (0.020) | (0.007) | (0.008) |
| Age of household head squared | -0.000 | -0.000* | -0.000* |
| | (0.000) | (0.000) | (0.000) |
| Education of most educated HH member (years) | -0.007 | 0.008 | -0.005 |
| | (0.019) | (0.010) | (0.009) |
| Log of landholding (Ha) | -0.187*** | 0.110*** | 0.027 |
| | (0.059) | (0.037) | (0.048) |
| Owns crop storage house (1/0) | 0.054 | 0.103*** | 0.048 |
| | (0.077) | (0.034) | (0.037) |
| Accessed credit (1/0) | 0.083 | 0.040 | 0.046 |
| | (0.100) | (0.034) | (0.036) |
| Accessed extension for production (1/0) | 0.107* | -0.005 | 0.015 |
| | (0.058) | (0.033) | (0.028) |
| Distance to road (Km) | 0.027 | -0.005 | 0.004 |
| | (0.018) | (0.006) | (0.007) |
| Distance to tobacco auction (Km) | -0.001 | -0.001 | -0.002 |
| | (0.005) | (0.002) | (0.001) |
| Distance to boma (Km) | -0.002 | 0.002*** | 0.001 |
| | (0.001) | (0.001) | (0.001) |
| Distance to weekly market (Km) | 0.005 | 0.002 | 0.002 |
| | (0.007) | (0.003) | (0.004) |
| Log of price of Urea fertilizer (MKW/Kg) | -0.051 | 0.174 | 0.251 |
| | (0.324) | (0.148) | (0.159) |
| Laspeyre's spatial price index | -0.009 | -0.007** | 0.003 |
| | (0.007) | (0.003) | (0.004) |
| Northern region | 0.851 | -0.353 | 0.132 |
| | (0.861) | (0.260) | (0.331) |
| Southern region | 0.715 | -0.110 | 0.064 |
| | (0.733) | (0.176) | (0.295) |
| Tropical-warm/sub-humid | 0.594 | 0.126 | 0.114 |
| | (0.472) | (0.157) | (0.160) |
| Tropical-cool/semiarid | 0.218 | -0.068 | 0.088 |
| | (0.437) | (0.096) | (0.146) |
| Tropical-cool/sub-humid | 0.796 | -0.674** | 0.275 |
| | (0.559) | (0.258) | (0.289) |
| Graded/Graveled | 0.567*** | -0.129 | 0.005 |
| | (0.194) | (0.130) | (0.151) |
| Dirt road (maintained) | 0.664*** | -0.104 | 0.085 |
| | (0.219) | (0.148) | (0.169) |
| Dirt track | 0.867*** | -0.032 | 0.218 |
| | (0.280) | (0.178) | (0.203) |
| Year (2013) | -0.016 | 0.134*** | 0.053 |
| | (0.082) | (0.037) | (0.037) |
| Constant | 13.576*** | 10.042*** | 7.132*** |
| | (1.807) | (1.935) | (2.597) |
| Observations | 2,023 | 2,023 | 2,023 |
| R-squared | 0.752 | 0.822 | 0.703 |

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses

## Appendix B

Table 4.A1: Impact of (consumption) Poverty on Nitrogen Use Efficiency
Dependent variable = maize yield (kg/ha)

| | Poor vs non-poor vs ultra-poor | Quintiles of consumption expenditure: 4th quintile omitted | 3rd quintile omitted | 2nd quintile omitted |
|---|---|---|---|---|
| Nitrogen application rate (Kg/ha) | 5.719*** | 8.442*** | 8.928*** | 6.064*** |
| | (1.675) [a] | (1.662) | (1.656) | (1.711) |
| Nitrogen application rate squared | 0.006 | 0.003 | 0.003 | 0.003 |
| | (0.011) | (0.011) | (0.011) | (0.011) |
| Non-poor * nitrogen application rate | 3.019*** | -- | -- | -- |
| | (1.013) | -- | -- | -- |
| Ultra-poor * nitrogen application rate | -1.445 | -- | -- | -- |
| | (1.425) | -- | -- | -- |
| First quintile * nitrogen application rate | -- | -3.109** | -3.596** | -0.731 |
| | -- | (1.320) | (1.409) | (1.291) |
| Second quintile * nitrogen application rate | -- | -2.378* | -2.865** | -- |
| | -- | (1.248) | (1.307) | -- |
| Third quintile * nitrogen application rate | -- | 0.487 | -- | 2.865** |
| | -- | (1.326) | -- | (1.307) |
| Fourth quintile * nitrogen application rate | -- | -- | -0.487 | 2.378* |
| | -- | -- | (1.326) | (1.248) |
| Fifth quintile * nitrogen application rate | -- | 1.212 | 0.725 | 3.590*** |
| | -- | (1.208) | (1.370) | (1.338) |
| Below recommended nitrogen application rate (1/0) | 91.500 | 94.233 | 94.233 | 94.233 |
| | (107.305) | (106.842) | (106.842) | (106.842) |
| Above recommended nitrogen application rate (1/0) | -202.685 | -196.010 | -196.010 | -196.010 |
| | (124.431) | (124.068) | (124.068) | (124.068) |
| Applied basal fertilizer on time (1/0) | 159.430*** | 155.490*** | 155.490*** | 155.490*** |
| | (57.476) | (57.731) | (57.731) | (57.731) |
| Applied organic fertilizer (1/0) | 223.318*** | 222.701*** | 222.701*** | 222.701*** |
| | (62.242) | (62.721) | (62.721) | (62.721) |
| Seed rate (Kg/ha) | 3.737*** | 3.727*** | 3.727*** | 3.727*** |
| | (1.081) | (1.081) | (1.081) | (1.081) |
| Used hybrid seed (1/0) | 71.286 | 73.391 | 73.391 | 73.391 |
| | (44.918) | (44.711) | (44.711) | (44.711) |
| Pure stand (1/0) | -129.637*** | -127.311*** | -127.311*** | -127.311*** |
| | (43.270) | (43.416) | (43.416) | (43.416) |
| Plot size (ha) | -1,117.205*** | -1,115.696*** | -1,115.696*** | -1,115.696*** |
| | (267.280) | (267.941) | (267.941) | (267.941) |
| Plot size squared | 500.586*** | 496.523** | 496.523** | 496.523** |
| | (192.381) | (193.110) | (193.110) | (193.110) |
| Labor (days) | 1.079*** | 1.088*** | 1.088*** | 1.088*** |
| | (0.298) | (0.297) | (0.297) | (0.297) |
| Soil is of good quality (1/0) | 198.950*** | 202.057*** | 202.057*** | 202.057*** |
| | (59.630) | (59.687) | (59.687) | (59.687) |
| Soil is of fair quality (1/0) | 172.211*** | 173.044*** | 173.044*** | 173.044*** |
| | (56.224) | (56.404) | (56.404) | (56.404) |
| Plot is sloppy (1/0) | -32.681 | -31.084 | -31.084 | -31.084 |
| | (43.396) | (43.488) | (43.488) | (43.488) |
| Plot is swampy (1/0) | -62.827 | -65.357 | -65.357 | -65.357 |
| | (61.061) | (60.789) | (60.789) | (60.789) |
| Soil is sandy clay (1/0) | 55.267 | 54.359 | 54.359 | 54.359 |
| | (44.512) | (44.690) | (44.690) | (44.690) |
| Plot show signs of erosion (1/0) | 24.967 | 26.643 | 26.643 | 26.643 |
| | (53.486) | (53.462) | (53.462) | (53.462) |
| Female plot manager (1/0) | -120.232** | -115.662** | -115.662** | -115.662** |
| | (51.837) | (51.684) | (51.684) | (51.684) |
| Age of plot manager (years) | 0.134 | 0.028 | 0.028 | 0.028 |
| | (1.667) | (1.667) | (1.667) | (1.667) |

[a] Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4.A1: Cont'd

| | Poor vs non-poor vs ultra-poor | Quintiles of consumption expenditure | | |
|---|---|---|---|---|
| | | 4th quintile omitted | 3rd quintile omitted | 2nd quintile omitted |
| Years of education of plot manager | 27.783*** | 27.197*** | 27.197*** | 27.197*** |
| | (6.974) [a] | (7.019) | (7.019) | (7.019) |
| African Adult Male Equivalent | 39.349** | 41.661** | 41.661** | 41.661** |
| | (19.117) | (19.140) | (19.140) | (19.140) |
| Dependency ratio (%) | 0.298 | 0.318 | 0.318 | 0.318 |
| | (0.295) | (0.294) | (0.294) | (0.294) |
| Household received extension service for production | 68.195 | 72.840 | 72.840 | 72.840 |
| | (47.446) | (47.069) | (47.069) | (47.069) |
| Distance to boma (Km) | -0.239 | -0.187 | -0.187 | -0.187 |
| | (0.916) | (0.918) | (0.918) | (0.918) |
| Tropic-warm/semiarid | 264.337** | 263.274** | 263.274** | 263.274** |
| | (102.819) | (102.957) | (102.957) | (102.957) |
| Tropic-warm/sub-humid | -71.668 | -73.191 | -73.191 | -73.191 |
| | (96.518) | (96.749) | (96.749) | (96.749) |
| Tropic-cool/semiarid | 73.098 | 71.527 | 71.527 | 71.527 |
| | (108.743) | (109.431) | (109.431) | (109.431) |
| Avg 12-month total rainfall(mm) for July-June | 1.302*** | 1.295*** | 1.295*** | 1.295*** |
| | (0.374) | (0.374) | (0.374) | (0.374) |
| Annual Mean Temperature (°C * 10) | -6.595*** | -6.599*** | -6.599*** | -6.599*** |
| | (2.063) | (2.060) | (2.060) | (2.060) |
| Year (2013) | 191.052*** | 190.778*** | 190.778*** | 190.778*** |
| | (49.390) | (49.586) | (49.586) | (49.586) |
| Constant | 678.523 | 668.890 | 668.890 | 668.890 |
| | (601.835) | (602.027) | (602.027) | (602.027) |
| Observations | 2,474 | 2,474 | 2,474 | 2,474 |
| Number of groups | 1,072 | 1,072 | 1,072 | 1,072 |

[a] Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4.A2: Impact of (asset) Poverty on Nitrogen Use Efficiency
Dependent variable = maize yield (kg/ha)

| | | Quintiles of consumption expenditure | | |
|---|---|---|---|---|
| VARIABLES | Poor vs non-poor vs ultra-poor | 4th quintile omitted | 3rd quintile omitted | 2nd quintile omitted |
| Nitrogen application rate (Kg/ha) | 6.033*** | 9.226*** | 7.933*** | 6.027*** |
| | (1.671) [a] | (1.593) | (1.714) | (1.661) |
| Nitrogen application rate squared | 0.005 | 0.003 | 0.003 | 0.003 |
| | (0.011) | (0.011) | (0.011) | (0.011) |
| Non-poor * nitrogen application rate | 3.505*** | -- | -- | -- |
| | (1.116) | -- | -- | -- |
| Ultra-poor * nitrogen application rate | -3.337*** | -- | -- | -- |
| | (1.294) | -- | -- | -- |
| First quintile * nitrogen application rate | -- | -6.521*** | -5.228*** | -3.321** |
| | -- | (1.245) | (1.314) | (1.293) |
| Second quintile * nitrogen application rate | -- | -3.200** | -1.907 | -- |
| | -- | (1.310) | (1.284) | -- |
| Third quintile * nitrogen application rate | -- | -1.293 | -- | 1.907 |
| | -- | (1.182) | -- | (1.284) |
| Fourth quintile * nitrogen application rate | -- | -- | 1.293 | 3.200** |
| | -- | -- | (1.182) | (1.310) |
| Fifth quintile * nitrogen application rate | -- | 2.725** | 4.018*** | 5.924*** |
| | -- | (1.279) | (1.382) | (1.420) |
| Below recommended nitrogen application rate (1/0) | 120.223 | 116.223 | 116.223 | 116.223 |
| | (102.842) | (101.653) | (101.653) | (101.653) |
| Above recommended nitrogen application rate (1/0) | -223.171* | -223.898* | -223.898* | -223.898* |
| | (121.086) | (120.661) | (120.661) | (120.661) |
| Applied basal fertilizer on time (1/0) | 176.226*** | 182.258*** | 182.258*** | 182.258*** |
| | (57.598) | (57.297) | (57.297) | (57.297) |
| Applied organic fertilizer (1/0) | 216.975*** | 209.230*** | 209.230*** | 209.230*** |
| | (61.885) | (61.685) | (61.685) | (61.685) |
| Seed rate (Kg/ha) | 3.754*** | 3.721*** | 3.721*** | 3.721*** |
| | (1.074) | (1.074) | (1.074) | (1.074) |
| Used hybrid seed (1/0) | 76.576* | 69.989 | 69.989 | 69.989 |
| | (44.691) | (44.856) | (44.856) | (44.856) |
| Pure stand (1/0) | -129.149*** | -131.991*** | -131.991*** | -131.991*** |
| | (43.183) | (43.101) | (43.101) | (43.101) |
| Plot size (ha) | -1,163.643*** | -1,188.183*** | -1,188.183*** | -1,188.183*** |
| | (268.448) | (267.446) | (267.446) | (267.446) |
| Plot size squared | 521.923*** | 522.911*** | 522.911*** | 522.911*** |
| | (189.264) | (188.044) | (188.044) | (188.044) |
| Labor (days) | 1.114*** | 1.132*** | 1.132*** | 1.132*** |
| | (0.297) | (0.295) | (0.295) | (0.295) |
| Soil is of good quality (1/0) | 200.991*** | 200.042*** | 200.042*** | 200.042*** |
| | (60.162) | (60.221) | (60.221) | (60.221) |
| Soil is of fair quality (1/0) | 170.074*** | 173.017*** | 173.017*** | 173.017*** |
| | (57.035) | (56.999) | (56.999) | (56.999) |
| Plot is sloppy (1/0) | -26.292 | -27.196 | -27.196 | -27.196 |
| | (43.089) | (42.546) | (42.546) | (42.546) |
| Plot is swampy (1/0) | -58.271 | -59.931 | -59.931 | -59.931 |
| | (60.906) | (60.637) | (60.637) | (60.637) |
| Soil is sandy clay (1/0) | 48.339 | 48.416 | 48.416 | 48.416 |
| | (44.249) | (43.999) | (43.999) | (43.999) |
| Plot show signs of erosion (1/0) | 31.667 | 30.423 | 30.423 | 30.423 |
| | (53.031) | (52.886) | (52.886) | (52.886) |
| Female plot manager (1/0) | -128.822** | -134.549*** | -134.549*** | -134.549*** |
| | (52.054) | (51.683) | (51.683) | (51.683) |
| Age of plot manager (years) | -0.724 | -1.228 | -1.228 | -1.228 |
| | (1.643) | (1.629) | (1.629) | (1.629) |

[a] Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4.A2: Cont'd

| | | Quintiles of consumption expenditure | | |
|---|---|---|---|---|
| | Poor vs non-poor vs ultra-poor | 4th quintile omitted | 3rd quintile omitted | 2nd quintile omitted |
| Years of education of plot manager | 24.144*** | 20.660*** | 20.660*** | 20.660*** |
| | (6.941) [a] | (7.087) | (7.087) | (7.087) |
| African Adult Male Equivalent | 26.967 | 26.243 | 26.243 | 26.243 |
| | (19.264) | (19.263) | (19.263) | (19.263) |
| Dependency ratio (%) | 0.294 | 0.314 | 0.314 | 0.314 |
| | (0.292) | (0.291) | (0.291) | (0.291) |
| Household received extension service for production | 63.811 | 61.877 | 61.877 | 61.877 |
| | (46.911) | (46.657) | (46.657) | (46.657) |
| Distance to boma (Km) | -0.210 | -0.190 | -0.190 | -0.190 |
| | (0.917) | (0.915) | (0.915) | (0.915) |
| Tropic-warm/semiarid | 319.041*** | 322.959*** | 322.959*** | 322.959*** |
| | (103.225) | (102.844) | (102.844) | (102.844) |
| Tropic-warm/sub-humid | -40.194 | -49.845 | -49.845 | -49.845 |
| | (96.263) | (96.163) | (96.163) | (96.163) |
| Tropic-cool/semiarid | 111.840 | 108.331 | 108.331 | 108.331 |
| | (109.620) | (110.156) | (110.156) | (110.156) |
| Avg 12-month total rainfall(mm) for July-June | 1.317*** | 1.293*** | 1.293*** | 1.293*** |
| | (0.371) | (0.371) | (0.371) | (0.371) |
| Annual Mean Temperature (°C * 10) | -7.364*** | -7.489*** | -7.489*** | -7.489*** |
| | (2.041) | (2.042) | (2.042) | (2.042) |
| Year (2013) | 193.375*** | 191.503*** | 191.503*** | 191.503*** |
| | (48.989) | (48.766) | (48.766) | (48.766) |
| Constant | 870.003 | 974.413 | 974.413 | 974.413 |
| | (598.819) | (598.939) | (598.939) | (598.939) |
| Observations | 2,474 | 2,474 | 2,474 | 2,474 |
| Number of groups | 1,072 | 1,072 | 1,072 | 1,072 |

[a] Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4.A3 Household Fixed Effects of Impact of (asset) Poverty on Nitrogen Use Efficiency

(Dependent variable = maize yield (kg/ha))

| VARIABLES | Non-poor vs poor | Non-poor vs poor vs ultra-poor | Quintiles of wealth index |
|---|---|---|---|
| Nitrogen application rate (Kg/ha) | 7.509*** | 7.444*** | 9.587*** |
| | (1.795) | (1.801) | (2.160) |
| Nitrogen application rate squared | -0.004 | -0.002 | -0.003 |
| | (0.013) | (0.013) | (0.013) |
| Poor * nitrogen application rate | -2.840** | -1.511 | -- |
| | (1.174) | (1.350) | |
| Ultra-poor * nitrogen application rate | -- | -4.524*** | -- |
| | | (1.642) | |
| First quintile * nitrogen application rate | -- | -- | -6.608*** |
| | | | (2.078) |
| Second quintile * nitrogen application rate | -- | -- | -3.701* |
| | | | (2.021) |
| Third quintile * nitrogen application rate | -- | -- | -2.770 |
| | | | (1.913) |
| Fourth quintile * nitrogen application rate | -- | -- | -2.759* |
| | | | (1.614) |
| Below recommended nitrogen application rate (1/0) | 11.453 | 27.604 | 22.229 |
| | (94.367) | (95.955) | (96.713) |
| Above recommended nitrogen application rate (1/0) | -160.867 | -165.339 | -172.509 |
| | (120.664) | (119.119) | (120.257) |
| Applied basal fertilizer on time (1/0) | 155.689 | 157.686 | 155.558 |
| | (94.644) | (95.923) | (94.724) |
| Applied organic fertilizer (1/0) | 170.894** | 172.179** | 167.035** |
| | (66.428) | (66.584) | (67.923) |
| Seed rate (Kg/ha) | 3.613*** | 3.660*** | 3.634*** |
| | (1.155) | (1.170) | (1.190) |
| Used hybrid seed (1/0) | 31.536 | 32.937 | 35.014 |
| | (52.075) | (51.223) | (51.430) |
| Pure stand (1/0) | -200.941*** | -202.059*** | -205.604*** |
| | (60.236) | (60.369) | (59.512) |
| Plot size (ha) | -2,083.328*** | -2,092.950*** | -2,094.284*** |
| | (437.279) | (436.727) | (439.132) |
| Plot size squared | 999.366*** | 1,010.714*** | 1,005.612*** |
| | (286.754) | (285.072) | (287.256) |
| Labor (days) | 1.105*** | 1.102*** | 1.088*** |
| | (0.375) | (0.377) | (0.377) |
| Soil is of good quality (1/0) | 122.552* | 119.094* | 114.371* |
| | (63.425) | (64.169) | (64.402) |
| Soil is of fair quality (1/0) | 215.178*** | 208.327*** | 205.228*** |
| | (59.752) | (60.294) | (60.421) |
| Plot is sloppy (1/0) | -46.090 | -47.303 | -44.864 |
| | (54.328) | (54.401) | (54.665) |
| Plot is swampy (1/0) | -112.265 | -110.937 | -116.446 |
| | (84.602) | (83.805) | (83.471) |
| Soil is sandy clay (1/0) | -29.934 | -29.668 | -24.925 |
| | (57.893) | (58.064) | (57.873) |
| Plot show signs of erosion (1/0) | 24.750 | 24.975 | 25.467 |
| | (83.398) | (82.835) | (81.752) |
| Female plot manager (1/0) | -153.693 | -150.987 | -156.415* |
| | (93.758) | (93.097) | (91.184) |
| Age of plot manager (years) | 1.238 | 1.173 | 1.046 |
| | (2.806) | (2.806) | (2.793) |

[a] Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 4.A3: Cont'd

| VARIABLES | Non-poor vs poor | Non-poor vs poor vs ultra-poor | Quintiles of wealth index |
|---|---|---|---|
| Years of education of plot manager | 17.695 | 17.041 | 15.436 |
| | (15.102) | (14.819) | (14.751) |
| African Adult Male Equivalent | 53.904 | 55.127 | 54.521 |
| | (44.296) | (44.483) | (44.183) |
| Dependency ratio (%) | 0.443 | 0.445 | 0.437 |
| | (0.399) | (0.396) | (0.397) |
| Household received extension service for production | -37.639 | -41.063 | -41.255 |
| | (71.063) | (70.092) | (68.846) |
| Distance to boma (Km) | -2.392* | -2.267 | -2.238 |
| | (1.373) | (1.384) | (1.375) |
| Tropic-warm/semiarid | 10.531 | 45.961 | 115.574 |
| | (349.590) | (350.001) | (346.544) |
| Tropic-warm/subhumid | 592.044 | 632.323 | 565.182 |
| | (495.457) | (499.451) | (472.718) |
| Tropic-cool/semiarid | -497.594** | -460.148** | -438.071** |
| | (210.675) | (211.017) | (208.667) |
| Avg 12-month total rainfall(mm) for July-June | 4.223* | 4.163* | 4.200* |
| | (2.173) | (2.166) | (2.161) |
| Annual Mean Temperature (°C * 10) | -19.563* | -19.418* | -19.726* |
| | (10.882) | (10.975) | (11.362) |
| Year (2013) | 155.173** | 156.160** | 153.007** |
| | (62.982) | (62.649) | (61.904) |
| Constant | 17.695 | 17.041 | 15.436 |
| | (15.102) | (14.819) | (14.751) |
| Observations | 2,474 | 2,474 | 2,474 |
| Number of groups | 1,072 | 1,072 | 1,072 |

[a] Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

## Appendix C

Stata Codes for Essay One

```
                    *****Testing for ommited variable bias using Oster(2015)******

 ***1: For per capita expenditure when agricultural productivity agricultural productiviture is measured by maize yield
xi: psacalc log_maizeyield2 rmax, model (reg log_exp log_maizeyield2 log_valueothercrops_median log_treeinctrim ///
hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have hhsize depend_ratio gender1 head_age ///
age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma ///
weekly_mk_km log_price_median_U price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 ///
i.year i.case_idd  [pweight=hh_wgt]) mcontrol (log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road ///
dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL ///
region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd) beta( .1730482) delta(1)

 ***2: For relative deprivation when agricultural productivity agricultural productiviture is measured by maize yield
xi: psacalc log_maizeyield2 rmax, model (reg log_relative_deprivationexp log_maizeyield2 log_valueothercrops_median ///
log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have hhsize depend_ratio gender1 head_age ///
age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km ///
log_price_median_U price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd ///
[pweight=hh_wgt]) mcontrol (log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km ///
log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd) beta(-0.0763355) delta(1)

 ***3: For per capita expenditure when agricultural productivity agricultural productiviture is measured by value of ouput per ha
xi: psacalc log_agproductivitymedian rmax, model (reg log_exp log_agproductivitymedian log_treeinctrim hh_livestock_num ///
log_offfarm_incomeimptrim log_agwagetrim other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ///
ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea  price_indexL ///
region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd [pweight=hh_wgt]) mcontrol ///
(log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL ///
region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd) beta(0.1296024) delta(1)

 ***4: For relative deprivation when agricultural productivity agricultural productiviture is measured by value of ouput per ha
xi: psacalc log_agproductivitymedian rmax, model (reg log_relative_deprivationexp log_agproductivitymedian log_treeinctrim hh_livestock_num ///
log_offfarm_incomeimptrim log_agwagetrim other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse ///
credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 ///
roadqual2 roadqual3 roadqual4 i.year i.case_idd [pweight=hh_wgt]) mcontrol (log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road ///
dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 ///
i.year i.case_idd) beta(-0.057952) delta(1)
```

Stata Codes for Essay One Cont'd

```
   *** Testing for endogeneity of agricultural productivity (maize yield) using control function approach ***
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: reg log_maizeyield2 log_dura log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim ///
log_agwagetrim other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse ///
credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 ///
agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 year2 caseid1 - caseid1035
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maize_ifinal.doc", title(Effect of Maize Yield(Kg/ha) ///
on Welfare) se  dec(3)  label ctitle ("Consumption") drop(caseid*) replace
predict resm2, res

svyset [pweight=hh_wgt], strata(stratum) singleunit(centered)
bsweights bsw, reps(100)  average (20) n(0) dots
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered) bsrweight(bsw*) bsn(20) vce(bootstrap)
svy boot: reg log_exp log_maizeyield2 resm2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim ///
log_agwagetrim other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ///
ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 ///
roadqual2 roadqual3 roadqual4 year2 caseid1 - caseid1035
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maize_ifinal.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(caseid*) append

svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered) bsrweight(bsw*) bsn(20) vce(bootstrap)
svy boot: reg lncalW log_maizeyield2 resm2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim ///
log_agwagetrim other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ///
ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 ///
roadqual2 roadqual3 roadqual4 year2 caseid1 - caseid1035
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maize_ifinal.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(caseid*) append


   *** Testing for endogeneity of agricultural productivity (maize yield) using control function approach ***
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: reg log_agproductivitymedian log_dura log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have ///
hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction ///
dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 ///
year2 caseid1 - caseid1035
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agpro_ifinal.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(caseid*) replace
predict resag2, res

svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered) bsrweight(bsw*) bsn(20) vce(bootstrap)
svy boot: reg log_exp log_agproductivitymedian resag2 log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have ///
hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction ///
dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 year2 ///
caseid1 - caseid1035
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agpro_ifinal.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  ///
dec(3)  label ctitle ("Consumption") drop(caseid*) append

svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered) bsrweight(bsw*) bsn(20) vce(bootstrap)
svy boot: reg lncalW log_agproductivitymedian resag2 log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have ///
hhsize depend_ratio gender1 head_age ///
age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea ///
price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 year2 caseid1 - caseid1035
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agpro_ifinal.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(caseid*) append
```

Stata Codes for Essay One Cont'd

```
*****Testing for ommited variable bias using Oster(2015)******

***5: For per capita caloric intake when agricultural productivity agricultural productiviture is measured by maize yield
xi: psacalc log_maizeyield2 rmax, model (reg lncalW log_maizeyield2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma ///
weekly_mk_km log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd [pweight=hh_wgt]) ///
mcontrol (log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL ///
region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd) beta(0.107429) delta(1)

***6: For relative deprivation in term of caloric  when agricultural productivity agricultural productiviture is measured by maize yield
xi: psacalc log_maizeyield2 rmax, model (reg log_relative_deprivationc log_maizeyield2 log_valueothercrops_median log_treeinctrim hh_livestock_num ///
log_offfarm_incomeimptrim other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ///
ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 ///
roadqual3 roadqual4 i.year i.case_idd [pweight=hh_wgt]) mcontrol (log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road ///
dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 ///
roadqual4 i.year i.case_idd) beta(-0.0854285) delta(1)

***7: For per caloric intake when agricultural productivity agricultural productiviture is measured by value of ouput per ha
xi: psacalc log_agproductivitymedian rmax, model (reg lncalW log_agproductivitymedian log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction ///
dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd ///
[pweight=hh_wgt]) mcontrol (log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL ///
region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd) beta(0.0936279) delta(1)

***8: For relative deprivation in term of caloric intake when agricultural productivity agricultural productiviture is measured by value of ouput per ha
xi: psacalc log_agproductivitymedian rmax, model (reg log_relative_deprivationc log_agproductivitymedian log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma ///
weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd [pweight=hh_wgt]) ///
mcontrol (log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL ///
region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd) beta(-0.081237) delta(1)
```

Stata Codes for Essay One Cont'd

```
               ***** Impact of agricultural productivity (maize yield) on the various measures of poverty  *****

*** per capita consumption expenditure
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: reg log_exp log_maizeyield2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road ///
dist_auction dist_boma weekly_mk_km log_price_median_U price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 ///
i.year i.case_idd
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maize.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(i.case_idd) replace
keep if e(sample)

*** relative deprivation in terms of per capita consumption expenditure ***
svy: reg log_relative_deprivationexp log_maizeyield2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim ///
log_agwagetrim other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro ///
dist_road dist_auction dist_boma weekly_mk_km log_price_median_U price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 ///
roadqual4 i.year i.case_idd
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maize.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Deprivation") drop(i.case_idd)

foreach var of varlist log_maizeyield2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim ///
other_have hhsize depend_ratio gender1 head_age hh_yrsh landhold_ha ag_storagehouse credit_access ext_pro dist_road dist_auction dist_boma ///
weekly_mk_km log_price_median_Urea price_indexL roadqual2 roadqual3 region1 region2 roadqual4 agzone2 agzone3 agzone4{
egen meann_`var' = mean(`var'), by(case_id)
}

*** poverty gap
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: twopm poverty_gap log_maizeyield2 log_valueothercrops_median  log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction ///
dist_boma weekly_mk_km log_price_median_U price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year meann*, ///
firstpart(logit)  secondpart(glm, f(b) l(logit))
margins, dydx(*) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maize.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3)  ///
label ctitle ("Consumption") drop(meann*)

*** severtiy of poverty
svy: twopm poverty_severity log_maizeyield2 log_valueothercrops_median  log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction ///
dist_boma weekly_mk_km log_price_median_U price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year meann*, ///
firstpart(logit)  secondpart(glm, f(b) l(logit))
margins, dydx(*) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maize.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) ///
label ctitle ("Consumption") drop(meann*)
```

Stata Codes for Essay One Cont'd

```
            ***** Impact of agricultural productivity (value of output per ha) on the various measures of poverty  *****

*** per capita consumption expenditure
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: reg log_exp log_agproductivitymedian log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have hhsize depend_ratio ///
gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma weekly_mk_km ///
log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agpro.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) ///
label ctitle ("Consumption") drop(i.case_idd) replace
keep if e(sample)

*** relative deprivation in terms of per capita consumption expenditure ***
svy: reg log_relative_deprivationexp log_agproductivitymedian  log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have ///
hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma ///
weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agpro.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) ///
label ctitle ("Deprivation") drop(i.case_idd)

*** poverty gap
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: twopm poverty_gap log_agproductivitymedian   log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have hhsize ///
depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma ///
weekly_mk_km log_price_median_U  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year meann*, ///
firstpart(logit)  secondpart(glm, f(b) l(logit))
margins, dydx(*) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agpro.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(meann*)

*** severtiy of poverty
svy: twopm poverty_severity log_agproductivitymedian log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have hhsize ///
depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma ///
weekly_mk_km log_price_median_U  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year meann*, ///
firstpart(logit)  secondpart(glm, f(b) l(logit))
margins, dydx(*) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agpro.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(meann*)
```

Stata Codes for Essay One Cont'd

```
***** Impact of agricultural productivity (maize yield) on the various measures of food security *****

*** per capita caloric intake
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: reg lncalW log_maizeyield2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road ///
dist_auction dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 ///
roadqual4 i.year i.case_idd
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maizec.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(i.case_idd) replace


***relative deprivation in terms per capita caloric intake ****
svy: reg log_relative_deprivationc log_maizeyield2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim ///
log_agwagetrim  other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro ///
dist_road dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 ///
roadqual3 roadqual4 i.year i.case_idd
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\maizec.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Deprivation") drop(i.case_idd)


***** Impact of agricultural productivity (value of output per ha) on the various measures of food security *****

*** per capita caloric intake
label var price_indexL "Laspeyres spatial price index"
svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: reg lncalW log_agproductivitymedian log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim  other_have hhsize ///
depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road dist_auction dist_boma ///
weekly_mk_km log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year i.case_idd
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agproc.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(i.case_idd) replace


***relative deprivation in term of caloric intake ***
svy: reg log_relative_deprivationc log_agproductivitymedian  log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim  ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road ///
dist_auction dist_boma weekly_mk_km log_price_median_Urea price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 ///
roadqual4 i.year i.case_idd
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\agproc.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Deprivation") drop(i.case_idd)
```

Stata Codes for Essay One Cont'd

```
******** Impact of agricultural produtivity (maize yield) on composite welfare ****

svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
xi: svy: oprobit poorins log_maizeyield2 log_valueothercrops_median log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim ///
other_have hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road ///
dist_auction dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 roadqual3 roadqual4 i.year meann*
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\poorinsecuremaize.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
 se  dec(3)  label ctitle ("Consumption") drop(meann*) replace
margins, dydx(*) predict(outcome(1)) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\poorinsecuremaize.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
 se  dec(3)  label ctitle ("Consumption") drop(meann*)
margins, dydx(*) predict(outcome(2)) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\poorinsecuremaize.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(meann*)
margins, dydx(*) predict(outcome(3)) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\poorinsecuremaize.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(meann*)

******** Impact of agricultural produtivity (value of output per ha) on composite welfare ****

svyset ea_id [pweight=hh_wgt], strata(stratum) singleunit(centered)
svy: oprobit poorins log_agproductivitymedian log_treeinctrim hh_livestock_num log_offfarm_incomeimptrim log_agwagetrim other_have ///
hhsize depend_ratio gender1 head_age age_squared hh_yrsh log_landhold_ha ag_storagehouse credit_access1 ext_pro dist_road ///
dist_auction dist_boma weekly_mk_km log_price_median_Urea  price_indexL region1 region2 agzone2 agzone3 agzone4 roadqual2 ///
roadqual3 roadqual4 i.year meann*
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\poorinsecureagpro.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("Consumption") drop(meann*) replace
margins, dydx(*) predict(outcome(1)) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\poorinsecureagpro.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("P1") drop(meann*)
margins, dydx(*) predict(outcome(2)) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\poorinsecureagpro.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("P2") drop(meann*)
margins, dydx(*) predict(outcome(3)) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\worldbank\both\models\poorinsecureagpro.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3)  label ctitle ("P3") drop(meann*)
```

## Stata Codes for Essay Two

```
******* Estimation of maize yield models ***
```

```
******* Estimation of maize yield models ***

*** Multilevel: Level 1 = plot; Level 2 = household
mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim  rec10_N_rate2 rec10_N_rate3 basal_1wk  basal2 organic  ///
seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio dist_boma agzone1 agzone2 agzone3 agtools_index1 durable_index1 rainfall_total temp year_2013 ///
||case_id: nitrogen_ratetrim if outlier==0,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Desktop\data_2015\essay1\Results\resultsml1.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3) label ctitle ("M HH") replace
keep if e(sample)
predict rh*, reffects
gen rrh_hh = rh1 + _b[nitrogen_ratetrim]
drop if rrh_hh<0

*** Multilevel: Level 1 = plot; Level 2 = garden
mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim  rec10_N_rate2 rec10_N_rate3 basal_1wk  basal2 organic  ///
seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio dist_boma agzone1 agzone2 agzone3 agtools_index1 durable_index1 rainfall_total temp year_2013 ///
||GIDD: nitrogen_ratetrim if outlier==0,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Desktop\data_2015\essay1\Results\resultsml2.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3) label ctitle ("M GIDD") replace
predict rg*, reffects
predict res, res
gen rrg_hh = rg1 + _b[nitrogen_ratetrim]
drop if rrg_hh<0
```

```
seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio dist_boma agzone1 agzone2 agzone3 agtools_index1 durable_index1 rainfall_total ///
temp year_2013 [pweight = hh_wgt], fe cluster(ea_id)
outreg2 using "C:\Users\fdarko\Desktop\data_2015\essay1\Results\results.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3) label ctitle ("HH FE")

*** Gerden fixed effects ***
xtset GIDD
xtreg yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim  rec10_N_rate2 rec10_N_rate3 basal_1wk  basal2 organic  ///
seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio dist_boma agzone1 agzone2 agzone3 agtools_index1 durable_index1 rainfall_total ///
temp year_2013  [pweight = hh_wgt], fe cluster(ta)
outreg2 using "C:\Users\fdarko\Desktop\data_2015\essay1\Results\results.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3) label ctitle ("Garden FE")
```

Stata Codes for Essay Two Cont'd

```
                                    ******* Estimation of maize yield models ***

*** Multilevel: Level 1 = plot; Level 2 = household
mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim  rec10_N_rate2 rec10_N_rate3 basal_1wk  basal2 organic  ///
seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio dist_boma agzone1 agzone2 agzone3 agtools_index1 durable_index1 rainfall_total temp year_2013 ///
||case_id: nitrogen_ratetrim if outlier==0,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Desktop\data_2015\essay1\Results\resultsml1.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3) label ctitle ("M HH") replace
keep if e(sample)
predict rh*, reffects
gen rrh_hh = rh1 + _b[nitrogen_ratetrim]
drop if rrh_hh<0

*** Multilevel: Level 1 = plot; Level 2 = garden
mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim  rec10_N_rate2 rec10_N_rate3 basal_1wk  basal2 organic  ///
seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio dist_boma agzone1 agzone2 agzone3 agtools_index1 durable_index1 rainfall_total temp year_2013 ///
||GIDD: nitrogen_ratetrim if outlier==0,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Desktop\data_2015\essay1\Results\resultsml2.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) ///
se  dec(3) label ctitle ("M GIDD") replace
predict rg*, reffects
predict res, res
gen rrg_hh = rg1 + _b[nitrogen_ratetrim]
drop if rrg_hh<0
```

Stata Codes for Essay Three

```
******* Multilevel model for estimalting difference in NUE across povery groups *****

                                        ***** consummption Poverty ***
mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim c.nitrogen_ratetrim#i.poor rec10_N_rate2 rec10_N_rate3 ///
basal_1wk organic  seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio ext_pro dist_boma agzone1 agzone2 agzone3  rainfall_total temp year_2013 ///
||case_id: nitrogen_ratetrim if outlier==0 & panelid==2,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Dropbox\lastessay\mlpoor1.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) label ctitle ("M Poor") replace
keep if e(sample)

mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim c.nitrogen_ratetrim#i.poor_3 rec10_N_rate2 rec10_N_rate3 ///
basal_1wk organic  seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio ext_pro dist_boma agzone1 agzone2 agzone3  rainfall_total temp year_2013 ///
||case_id: nitrogen_ratetrim if outlier==0 & panelid==2,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Dropbox\lastessay\mlpoor2.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) label ctitle ("M Poor_3") replace
keep if e(sample)

mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim c.nitrogen_ratetrim#ib5.consquin rec10_N_rate2 rec10_N_rate3 ///
basal_1wk  organic  seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio ext_pro dist_boma agzone1 agzone2 agzone3  rainfall_total temp year_2013 ///
||case_id: nitrogen_ratetrim if outlier==0 & panelid==2,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Dropbox\lastessay\mlpoor3.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) label ctitle ("M Quin") replace
keep if e(sample)


                                             ***** Asset poverty ****
mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim c.nitrogen_ratetrim#i.poor_asset rec10_N_rate2 rec10_N_rate3 ///
basal_1wk  organic seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio ext_pro dist_boma agzone1 agzone2 agzone3  rainfall_total temp year_2013 ///
||case_id: nitrogen_ratetrim if outlier==0 & panelid==2,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Dropbox\lastessay\mlwealth1.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) label ctitle ("M Poor") replace
keep if e(sample)

mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim c.nitrogen_ratetrim#i.poor_asset_3 rec10_N_rate2 rec10_N_rate3 ///
basal_1wk organic seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio ext_pro dist_boma agzone1 agzone2 agzone3  rainfall_total temp year_2013 ///
||case_id: nitrogen_ratetrim if outlier==0 & panelid==2,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Dropbox\lastessay\mlwealth2.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) label ctitle ("M Poor_3") replace
keep if e(sample)

mixed yield_mediantrim nitrogen_ratetrim c.nitrogen_ratetrim#c.nitrogen_ratetrim c.nitrogen_ratetrim#ib5.wealthquin rec10_N_rate2 rec10_N_rate3 ///
basal_1wk organic seed_ratetrim hybrid pure_stand GPS_hatrim  GPS_hatrim_sq labor_hftrim soil_good soil_fair slope_yes swamp_yes soilSANCLAY erosion_yes  ///
plotgender_female plotage plot_edu_yrs AAME depend_ratio ext_pro dist_boma agzone1 agzone2 agzone3  rainfall_total temp year_2013 ///
||case_id: nitrogen_ratetrim if outlier==0 & panelid==2,  pweight(hh_wgt) vce(robust)
outreg2 using "C:\Users\fdarko\Dropbox\lastessay\mlwealth3.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) label ctitle ("M Quin") replace
keep if e(sample)
```

Stata Codes for Essay Three Cont'd

```
******* Double Hurdle Model of crouding out ******

use "C:\Users\fdarko\Dropbox\lastessay\craggit.dta", replace

                              **** auxilliary regression of demand for subsidized fertilizer ***
tobit  sub_ferttrim headlive wealthindex landholding_hatrim  depend_ratio  head_female dist_roadtrim dist_popcentertrim  price_nitrogen dist_lean ///
rainfall_lastyr region2 region3 sq_index1 year_2013 bar* [pweight = hh_wgt], ll(0)
predict double xb if e(sample), xb
gen double residual = `depvar' - xb if e(sample)

                              ****** Hurdle 1 *********
tobit  sub_ferttrim headlive wealthindex landholding_hatrim  depend_ratio  head_female dist_roadtrim dist_popcentertrim  price_nitrogen dist_lean ///
rainfall_lastyr region2 region3 sq_index1 year_2013 bar* [pweight = hh_wgt], ll(0)
predict double xb2 if e(sample), xb
gen double residual1 = `depvar' - xb if e(sample)

probit commm  sub_ferttrim residual wealthindex landholding_hatrim  depend_ratio head_female dist_roadtrim dist_popcentertrim year_2013 price_nitrogen dist_lean ///
rainfall_lastyr region2 region3  sq_index1 bar* [pw = hh_wgt] if panelid==2
keep if e(sample)
margins, dydx(*)
restore
end

bootstrap, reps(250) seed(123) cluster(case_id) idcluster(newid) : myboot
margins, dydx(*) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\lastessay\dh1smodel.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) label ctitle ("M Quin") replace


                            ****** Hurdle 2 *********
truncreg comm_ferttrim sub_ferttrim wealthindex landholding_hatrim  depend_ratio head_female dist_roadtrim dist_popcentertrim year_2013 price_nitrogen dist_lean ///
rainfall_lastyr region2 region3  sq_index1 bar* [pweight = hh_wgt], ll(0) cluster(case_id)
margins, dydx(*) post
outreg2 using "C:\Users\fdarko\Desktop\data_2015\lastessay\dh2smodel.doc", title(Effect of Maize Yield(Kg/ha) on Welfare) se  dec(3) label ctitle ("M Quin") replace

                            ***** Generating APE
xi: craggit commm sub_ferttrim res wealthindex landholding_hatrim AAME depend_ratio head_gender dist_roadtrim dist_popcentertrim year_2013 price_nitrogen dist_lean ///
rainfall_lastyr region2 region3 region2 region3  sq_index1 bar* [pw = hh_wgt] if panelid==2  ///
, second(comm_ferttrim sub_ferttrim wealthindex landholding_hatrim AAME depend_ratio head_gender dist_roadtrim dist_popcentertrim year_2013 price_nitrogen dist_lean ///
rainfall_lastyr region2 region3 region2 region3  sq_index1 bar*  )
estimates store m2

predict x1g_endog, eq(Tier1)
predict x2b_endog, eq(Tier2)
predict sigma_endog, eq(sigma)
gen dEy_dsubfert_endog = [Tier1]_b[sub_ferttrim]*normalden(x1g_endog)*(x2b_endog+sigma_endog*(normalden(x2b_endog/sigma_endog)/normal(x2b_endog/sigma_endog))) ///
+[Tier2]_b[sub_ferttrim]*normal(x1g_endog)*(1-(normalden(x2b_endog/sigma_endog)/normal(x2b_endog/sigma_endog))*(x2b_endog/sigma_endog+ ///
(normalden(x2b_endog/sigma_endog)/normal(x2b_endog/sigma_endog))))
sum dEy_dsubfert_endog
```

VITA

# VITA

Francis Addeah Darko
Graduate School, Purdue University

## FORAMAL EDUCATION

PhD. Agricultural Economics, Purdue University (2016)

- **Dissertation:** Essays on Malawian Agriculture: Micro-level welfare impacts of agricultural productivity; profitability of fertilizer Use; and targeting of fertilizer Subsidy Programs (Co-chairs: Prof. Jacob Ricker-Gilbert and Prof. Gerald Shively)

M.S. Agricultural Economics, Purdue University (2011)

- **Thesis:** Consumer Preference for farmed tilapia and catfish in Ghana and Kenya:
 Opportunities for competitive and efficient aquaculture (Chair: Prof. Quagrainie)

BSc. Agricultural Economics, University of Ghana (2008)

- **Thesis:** Export Demand for Ghana's Palm Oil (Advisor: Dr. Kuwornu).

Short-term Exchange Program, Tokyo University of Agriculture and Technology (2006 – 2007)

- **Courses:** Intercultural Communication, International Cooperation of Sci. and Tech., Japanese Science and Technology, Japanese Culture, Japanese Language etc.

## OTHER ANALYTICAL TRAININGS

1. **Commitment to Equity (CEQ)**: World Bank, Washington, DC; July, 2016
    - Methodology for analysing the impacts of fiscal policy (taxation and public expenditures) on poverty and income inequality.
2. **EUROMOD:** World Bank, Washington, DC; July, 2016
    - Tax-benefit microsimulation modelling strategies using EUROMOD, the EU-wide tax-benefit microsimulation model, as an example.
3. **Multilevel Modelling**. Statistical Horizons, Temple University, Philadelphia. March, 2014.
    - The use of multilevel modelling approach in development research

HONORS/AWARDS

- **Outstanding Future Leader's Forum Participant,** 2011 meeting of the Association of International Agriculture and Rural Development (AIARD). $5000 cash award.
- **Honourable Mention**, 2011 Purdue University's Sigma Xi Graduate Student Poster Competition. $200 cash award
- **$1200 travel grant** from Bill and Belinda Gates Foundation for a presentation at the 3rd AAAE Conference in Cape Town, South Africa.
- **Best graduating student** in Agricultural Economics, 2008. University of Ghana.
- **First class honours** in BSc. Agricultural Economics, 2008. University of Ghana.
- **Best second-year Agricultural Science student**, Univ. of Ghana. Awarded a Japanese government scholarship to participate in an exchange program in Tokyo Univ. of Agric. and Tech., Japan.

WORK EXPERIENCE

1. **The World Bank: Jakarta, Indonesia**

   Economist, GF (Starting on 09/12/2016): Poverty and Equity Global Practice

2. **The World Bank: Washington, DC.**

   *A.* Short Term Consultant (05/15/2015 – 05/18/2016): DECRG (Poverty and Inequality Unit)

- Worked on the agriculture chapter of the Malawi Poverty Assessment report (P148050)
  - Created variables from two LSMS large databases of Malawi's (IHS3 and IHPS)
  - Analysed the relationship between household welfare and agricultural productivity
  - Analysed the determinants of agricultural productivity
  - Analysed the current state of agriculture in Malawi
  - Drafted the agriculture chapter based on the above analyses

   *B.* Short Term Consultant (10/12/2015 to 04/10/2016): DECRG (Environment & Energy)
   - Worked with a team to develop a common set of variables and labels across the country panels of the LSMS countries to study how farmers respond to prices.
   - Developed Stata code to organize the data in a common structure

- Documented the code and the steps required to recreate the structure and pooled data set

*C.* Short Term Consultant (10/12/2015 to 04/02/2016): Agriculture GP, EAP.

- Analysed the determinants of agricultural productivity in Myanmar
- Analysed the current state of agriculture in Myanmar

**3. Centre for Agricultural Research and Development (CARD), Lilongwe University of Agriculture and Natural Resources (LUANAR).**

Vising Scholar (10/2014 – 11/2014)

- Capacity building: Co-instructed faculty members of LUANAR and researchers of public institutions in the use of Stata for data management and data analyses.
- Research: Analysed the profitability of fertilizer use in Malawi

Survey consultant (04/2016)

- Capacity building: Co-trained nine enumerators for the administration of a survey aimed at understanding the nature of the land rental market in Malawi.

**4. Department of Agricultural Economics, Purdue University.**

Graduate Research Assistant (08/2009 to Present)

- Analysed the how family food budgets can be minimized while meeting nutritional requirements
- Analysed consumer preference for fish and fish consumption patterns in Ghana and Kenya
- Analysed the prospects of family businesses in the Mid-west region of USA
- Investigated the effect of Malawi's farm input subsidy program on maize prices
- Investigating the profitability of fertilizer use in Malawi
- Investigating farmers that should be targeted for Malawi's farm input subsidy program

Teaching assistant for AGEC 512, a graduate level linear programming class (Fall 2011)

- Assisted students in doing homework assignments
- Assisted students in using GAMS to analyse data for class project

**5. Department of Agricultural Economics and Agribusiness, University of Ghana.**

Research assistant (10/2008 – 08/2009)

- Analysed data and wrote a report on living standards in the Upper West region of Ghana
- Analysed data for a report on living standards in the Northern region of Ghana

Teaching assistant, (10/2008 – 08/2009)

- Held tutorials for students; assisted students in doing homeworks; graded homeworks and exams for the three undergraduate courses in micro and macro-economic theory.

Survey Consultant (July, 2008)

- Administered survey to marketers and consumers of organic agricultural produce for a study on organic agriculture in Ghana

RESEARCH EXPERIENCE

- Publications

**Darko F.A.,** Quagrainie K.K., Chenyambuga S. "Consumer Preference for Farmed Tilapia in Tanzania: A Choice Experiment Analysis". Journal of Applied Aquaculture. DOI: 10.1080/10454438.2016.1169965.

Palacios-Lopez, A., Kilic, T. and **Darko, F.A.** (2015). "Agricultural Productivity and Poverty in Malawi, 2010-2013" in "Malawi Enhanced Poverty Diagnostic - P154211". The World Bank

Ricker-Gilbert, J., Mason, N., **Darko, F.A.** and Tembo S.T. (2013). What are the Effects of Input Subsidy Programs on Maize Prices? Evidence from Malawi and Zambia. Agricultural Economics 44, 1-6.

**Darko F.A.,** Allen, B., Mazunda J., Rahimzai R., and Dobbins C. (2013). "Cost-Minimizing Food Budgets in Ghana." Journal of Development and Agricultural Economics, Vol. 5(4), pp. 135-141.

Kuwornu, J.K.M., **Darko F.A.,** Osei-Asare, Y.B., and Egyir, I.S. (2009). "Exports of Ghana's Palm Oil: A Demand Analysis", Journal of Food Distribution Research, 40(1), 90-96.

**Darko F.A**, Quagranie, K.K. Dennis, J.H., Olynk, N. and Doering, O. "Consumer Preference for Farmed Tilapia and Catfish in Ghana and Kenya" Marine Resource Economics (Under Review)

**Darko, F. A.,** Palacios-Lopez, A, Kilic, T and Ricker-Gilbert, J "To what extent does agricultural productivity affect household welfare? Evidence from rural Malawi." Journal of Development Studies (Under Review)

- Working papers

**Darko, F.**, Ricker-Gilbert, J. Shively, G. and Kilic, T and Florax, R. "Profitability of Inorganic fertilizer use in Sub-Sahara Africa: A spatial analysis from Malawi."

**Darko, F. A.,** Ricker-Gilbert, J. and Kilic, T. "The displacement-productivity trade-off in the targeting of subsidized farm inputs in SSA: Evidence from Malawi".

**Darko F.A**. and Eales, J. "Meat Demand During and After the Great Recession."

- Conference and Workshop Presentations

**Darko, F.A.** "Increasing Smallholder Input Profitability and Fertilizer Use Efficiency in Malawi" Closing Workshop on Guiding Investments in Sustainable Agriculture Intensification in Malawi. Lilongwe, Malawi, 21st April, 2016. **ORAL**

**Darko, F. A.** "To what extent does agricultural productivity affect the household welfare? Evidence from Malawi." at the Joint AAEA & WAEA Annual Meeting, San Francisco, July 26-28, 2015. **POSTER**

**Darko, F.**, Ricker-Gilbert, J. Shively, G. and Kilic, T. "Where is Fertilizer (Un) profitable in Africa: Spatial Evidence from Malawi." at the 2014 Inaugural Economics Association of Malawi (ECAMA) Research Symposium, October 8-10, 2014. Lilongwe, Malawi. **ORAL**

**Darko, F. A.,** Ricker-Gilbert, J. Shively, G. and Kilic, T. "Profitable of Fertilizer Use in Malawi: A Spatial Econometrics Approach." AAEA Annual Meeting, July 27-29, 2014. Minneapolis, USA. **ORAL**

**Darko, F.A.** "Increasing Smallholder Input Profitability and Fertilizer Use Efficiency in Malawi" Inception Workshop on Guiding Investments in Sustainable Agriculture Intensification in Malawi. Lilongwe, Malawi, 19th September, 2013. **ORAL**

**Darko, F.A.** and Ricker-Gilbert, J. "Economic Efficiency of Subsidized Farm Inputs: Evidence from Malawi Maize Farmers" 4th International Conference of the African Association of Agricultural Economists, September 22-25th, 2013. Hammamet, Tunisia. **POSTER**

**Darko F.A.** and Eales, J. "Meat Demand During and After the Great Recession." AAEA & CAES Joint Annual Meeting, August 4-6, 2013. Washington, DC. **ORAL**

**Darko, F. A.**, Quagrainie, K. K., Dennis, J., Olynk, N. and Doering, O. "Consumer Preference for Farmed tilapia and Catfish in Ghana and Kenya." Aquaculture America, Feb. 28th – Mar. 3rd, 2011. New Orleans, Louisiana. **ORAL.**

**Darko, F. A**., Quagrainie, K. K., Dennis, J., Olynk, N. and Doering, O. "Consumer Preference for Farmed tilapia in Ghana and Kenya: A Stated Preference Approach." Aquaculture America, Feb. 28th – Mar. 3rd, 2011. New Orleans, Louisiana. **POSTER.**

**Darko, F.A**, Allen, B., Mazunda, J., Rahimzai, R. and Dobbins, C. "Cost-Minimizing Food Budgets in Ghana", 3rd AAAE/49th AEASA Conference, Sept. 19th-23rd, 2010. Cape Town, South Africa. **POSTER.**

LEADERSHIP POSITIONS

- **Graduate Students and Young Scholars Representative** of the African Association of Agricultural Economists (September 2013 to Present)
- **International Recruitment Advisory Board member** (Fall, 2010 to present)
- **Senator** for the Department of Agricultural Economics at the Purdue University Graduate Student Government (December 2012 to August 2014)